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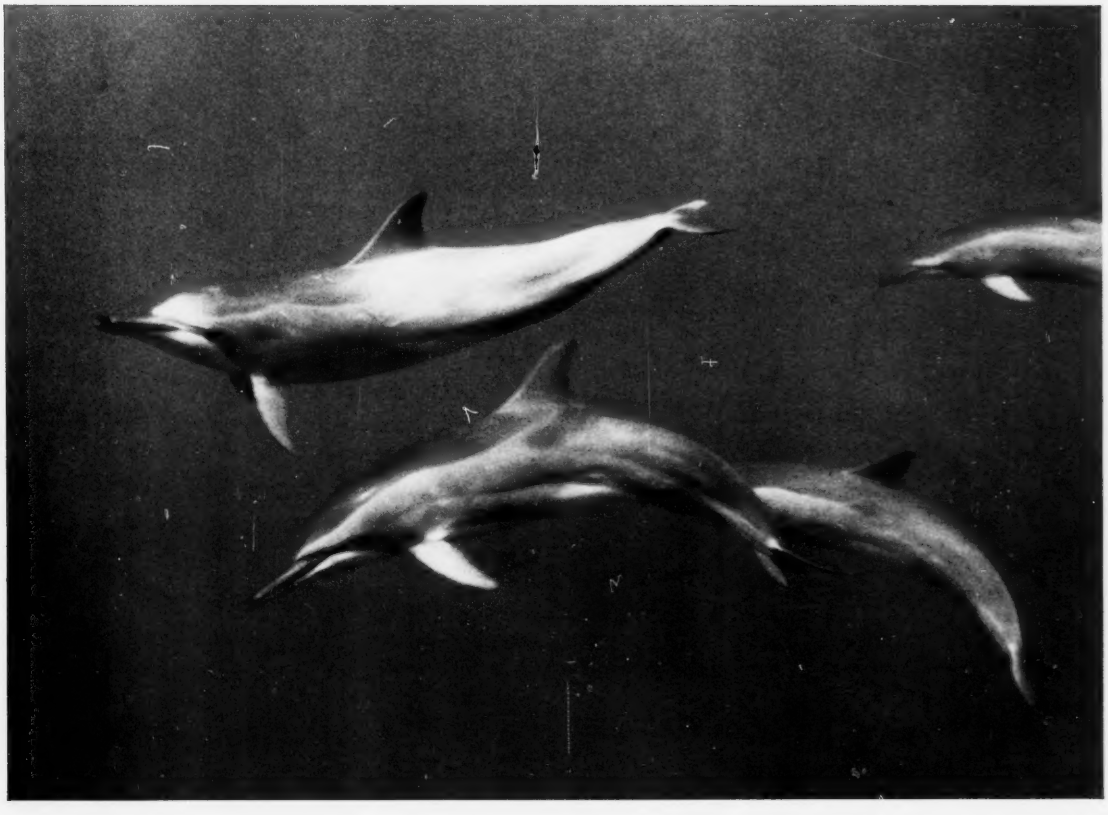

The Spinner Dolphin

Marine Fisheries REVIEW

On the cover: Spinner dolphins off Puerto La Cruz, Venezuela, 1979. Photograph by Giuseppi di Sciara, courtesy of S. Leatherwood, Hubbs Sea World Research Institute.

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Marine Resource Management Under Uncertainty: The Case of Eastern Spinner Dolphin Depletion

JAMES K. SEBENIUS

Marine resource management regimes often require decisions that must be based on uncertain data and models. Despite theoretical and practical advances, one cannot count all the fishes in the sea. Models have difficulty capturing the complex interactions of species with other species and with their environment.

Data are frequently incomplete and uncertain, key scientists disagree, and fishery models are often flawed. For example, the Bristol Bay salmon run for 1975 was predicted to be 12 million sockeye with an 80 percent confidence interval between 6.2 and 17.8 million. The actual inshore run for this long and intensively studied stock complex was 24 million fish (University of Washington, 1976).

Many authors have commented on the frequent inadequacies of bioeconomic theory and data (Crutchfield, 1972; Larkin, 1972). It is clear that great uncertainties will characterize forthcoming management decisions. This paper examines the inherent role of uncertainty in such management situations and offers the case of eastern spinner dolphin, *Stenella longirostris*, depletion as an example where a special application of probability theory helped to clarify a difficult determination.

Where the descriptive and predictive powers of fishery scientists are strong, management can be the beneficiary (Cushing, 1974). Decisions, however, must frequently be made before scientific information is conclusive. Managers typically face the problem of making good decisions in the presence of scientific uncertainty and policy constraints.

Fortunately, there are aids to good management in such situations. It is often possible to describe uncertainty in probability terms. Once judgments are expressed in this form, the logic of mathematics is available to assist in making consistent choices. "Doing the best one can with what one has" should be the desideratum for management determinations where there is scientific dispute, uncertain data, or inadequate models.

Porpoise, Tuna, and the Marine Mammal Protection Act

A situation embodying such disagreement and uncertainty recently arose in an application of the Marine Mammal Protection Act (MMPA) of 1972 (U.S. Code, 1972). The legal and policy context is important to understand. This Act was passed, in part, because of concern over the porpoise kill incidental to commercial tuna fishing.

Tuna fishermen have observed that yellowfin tuna often associate with certain species of porpoise. When porpoise are sighted, speedboats are used to herd them to the area where a large purse seine will be deployed. The tuna follow the porpoise and are captured when the net is drawn closed. This procedure is called fishing "on porpoise" and began in the latter 1950's.

In 1975, for example, yellowfin tuna caught "on porpoise" represented 72 percent of the total U.S. yellowfin tuna catch, and 43 percent of the total U.S. tuna catch (National Marine Fisheries Service, 1975). Despite fisherman efforts to release the porpoise, many become entangled in the nets and drown. Over 300,000 porpoise were killed in 1971, the year before the MMPA was passed.

The MMPA was based on a concern that certain stocks of marine mammals were threatened by extinction or depletion. It declared that species should not be permitted to fall below their "optimum sustainable population (OSP)." According to the Act, "The term 'optimum sustainable population' means, with respect to any population stock, the number of animals which will result in the maximum productivity of the population of the species, keeping in mind the optimum carrying capacity of the habitat and the health of the ecosystem of which they form a constituent element" (U.S. Code, 1972).

The MMPA adopted an immediate goal that porpoise kill and serious injury incident to commercial fishing be reduced "to insignificant levels approaching zero." Nevertheless, the Secretary of Commerce could issue permits which allowed the taking of marine mammals so long as "such taking will not be to the disadvantage of those species and population stocks and will be consistent with the purposes and policies" of the Act. The Secretary had issued such permits

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to the tuna industry. In May 1976, however, these permits were invalidated by court action (Richey, 1976). The District of Columbia Court of Appeals upheld this decision the following August. The decision required the imposition of a quota and an analysis of its impact on optimum sustainable population. Unless new regulations were issued, no setting on porpoise could occur after 1 January 1977, with consequent economic impact on the industry.

The Eastern Spinner Dolphin and OSP

To issue new regulations before 1977 for incidental porpoise take, the National Marine Fisheries Service was required to make a number of findings. One requirement was a determination whether the eastern spinner dolphin was depleted. Legally, this would have been the case if the current eastern spinner dolphin stock size was below the range of its "optimum sustainable population." This determination would have been relatively easy if the data were good and scientists were agreed on the precise values of stock size and OSP. In that happy event, the two values could have been compared simply. This, however, was not the case.

A conference of 12 distinguished marine scientists was convened in La Jolla, Calif., in August 1976 to address issues of population size and OSP for numerous porpoise stocks. After studying the data, they decided that there is "a range of population sizes — between that giving the maximum net productivity [MNP] and the maximum population possible within the carrying capacity of the ecosystem — which is consistent with the MMPA" (SWFC, 1976). Thus, OSP should not be interpreted as a single number but rather as a range of population sizes. The eastern spinner dolphin depletion determination turned on whether the species' 1976 stock size was below the lower end of the range of OSP. The workshop participants made estimates of porpoise stock sizes before tuna purse seining began and estimates of present stock sizes as percentages of this unexploited population level.

On the basis of the best available data and models, the workshop participants were unable to determine precise values for the present (1976) stock size and the lower limit of OSP. Instead, they specified a range of values for each. They felt that the lower limit of the OSP range occurred at a level somewhere between 50 and 70 percent of the original porpoise stock size. Their estimate of the current eastern spinner dolphin population was within a range of 37-75 percent of the unexploited population size.

A Probabilistic Analysis

Because of the court decisions and the strict regulatory timetable, a prompt finding on the status of eastern spinner dolphin stocks had to be made by the National Marine Fisheries Service. The available scientific knowledge about stock sizes and the lower limit of OSP obviously did not justify picking single numbers in the ranges for comparison. Instead, the question was how to use this uncertain scientific information, consisting of ranges rather than precise figures, to arrive at a finding of whether or not the present eastern spinner dolphin stock was below the lower end of its optimum sustainable population range. One way to proceed was to describe the uncertainty formally and then to determine the probability that the current stock size was below the lower limit of the OSP range. This exercise, along with the advice of key scientists and the Marine Mammal Commission, could then guide the finding of depletion.

There were three steps involved in determination: 1) Translate the state of knowledge about the lower limit of OSP into probabilistic terms; 2) do the same for the current stock size of the eastern spinner dolphin; and 3) compare the two quantities stochastically.

To begin, consider what the final workshop report (SWFC, 1976) said about OSP: "The participants believe therefore that any porpoise stock whose abundance is less than 50% of the unexploited level is probably below the MNP level [equal to the lower limit of OSP], and that any stock much more than 70% of the unexploited stock is probably above the MNP level [lower limit of OSP] . . . Most of the participants believe that there is insufficient scientific evidence to select a particular value of the proportion of the unexploited porpoise population necessary for maximum net production [the lower limit of OSP] within the range of 50% to 70%."

One probabilistic interpretation of this statement was there was an equal chance of OSP occurring at any point within the 50-70 percent range. Analytically, this indicated a uniform probability distribution on the 50-70 percent interval (Fig. 1). Thus, it was equally likely in this interpretation that OSP was at 52, 57, or 65 percent of the unexploited level, for example.

It is worth noting that the translation of this state of knowledge into probability terms is not based on a relative-frequency concept of probability (von Mises, 1941). Instead, it considers probability to be a description of uncertainty. A brief elaboration of the basis of this interpretation may be helpful.

Numerous contributors to the theory of probability have conceived of probability as a rational measure of belief (i.e., see Jeffreys, 1961; or Savage, 1954); historical treatments are contained in de Finetti (1972) or Raiffa (1968). Under this approach, past information or analysis about the uncertain event under consideration should be taken into account in assigning probabilities to the different possible outcomes. If it were relevant, information about the relative frequency with which the event occurred would affect the probability assessment. It is important to note, however, that this "subjectivist" concept of probability — loosely typified by statements like "there is a 40 percent chance of rain" or "I'll give you five-to-one odds on the Yankees" — can be rigorously extended to events that cannot be repeated under identical conditions or that do not admit a long-run, relative-frequency interpretation. If certain principles are adhered to for making consistent probability assessments, it is possible to prove that the resulting measure satisfies the standard requirements for the definition of probability. The usual mathematics of probability can then be used to work with such formal descriptions of the uncertain quantity.

With this interpretation of probability statements in mind, the second step in the analysis of porpoise depletion re-

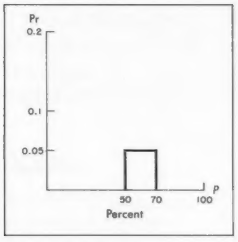

Figure 1.—Density function for lower end of OSP range (P).

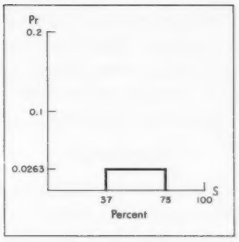

Figure 2.—Density function for stock size (S) as a percentage of unexploited population.

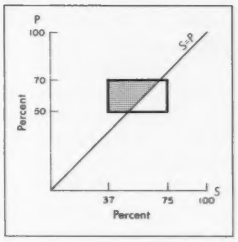

Figure 3.—Comparison of stock size (S) and OSP (P).

quired a description of the uncertainty in estimates of stock size (given as a percentage of the unexploited population). This number depended on estimates of the eastern spinner dolphin population before purse seining began, upon net recruitment rates, upon reproductive response lags, and upon alternative historical mortality vectors. Based on their information, the workshop participants concluded that the 1976 stock size was somewhere between 37 and 75 percent of the unexploited population level (SWFC, 1976). Rather than to combine the underlying factors probabilistically, an appropriate initial description of this uncertainty was to say that there was an equal chance of the true value occurring at any point from 37 to 75 percent of the unexploited population level. Thus, a density function as in Figure 2 is indicated.

The third step is to compare the lower limit of the OSP range and the stock size. It appears warranted to consider OSP and current stock size to be stochastically independent random variables, since knowledge of the distribution of one variable indicates nothing about that of the other.

Let S be the current population of the eastern spinner dolphin and let P be the lower limit of the OSP range. Their probability density functions can then be represented as

$$f(S) = \begin{cases} 0.0263, & 37<S<75 \\ 0, & \text{otherwise,} \end{cases}$$

and

$$g(P) = \begin{cases} 0.05, & 50<P<70 \\ 0, & \text{otherwise.} \end{cases}$$

The rectangle in the SP-plane is the region over which the joint density function of S and P is nonzero (Fig. 3). Note that above the line $S=P$, S is less than P, or the stock is depleted. The idea, then, is to calculate the probability of the event that S is less than P; that is, to determine the chances of being in the shaded area. Since the joint probability density function— the product of the independent marginal density functions of S and P—is constant above the region in this case, the depletion chance can be obtained by multiplying the area of the shaded region by the joint density function. Thus,

$$\begin{aligned} \Pr(S<P) &= (\text{shaded area in diagram}) \\ &\quad (\text{joint p.d.f.}) \\ &= [(13)(20) + (0.5)(20)(20)] \\ &\quad [(0.05)(0.0263)] \\ &= 0.6049. \end{aligned}$$

Hence, under these assumptions, there was a greater than 60 percent chance that stock size was below the lower limit of OSP.

This methodology could be extended to more complicated descriptions of the uncertainty. The only change in the analysis is that appeals to calculus or special properties of the random variables would be necessary.

For example, a more appropriate description of the uncertainty expressed in the workshop report might have been that the chances of OSP occurring at the 60 percent level are highest, with the probability falling off normally toward the 50 percent and 70 percent levels. A normal density function with a mean of 60 percent and standard deviation of 5 percent would imply a greater than 95 percent chance that the lower OSP limit was in the 50-70 percent interval with a 2.5 percent chance that the true value was greater than 70 percent, and a 2.5 percent chance that it was less than 50 percent. To see this, note that

$$\begin{aligned} &\Pr(50<P<70) \\ &\quad = \Pr\left(\frac{50-60}{5} < \frac{P-60}{5} < \frac{70-60}{5}\right) \\ &\quad = \Pr(-2<Z<2) \\ &\quad = 0.955, \end{aligned}$$

where Z is N(0,1). To construct a similar distribution for stock size, a normal density function with a 56 percent mean and a 9.5 percent standard deviation was indicated.

Stock size will be less than the lower limit of OSP where S is less than P. If the new variable D is defined as $P-S$, then the area where D is greater than zero is the region of interest. Now D is a random variable distributed as the difference of two independent normal random variables. Thus, D has a mean equal to the difference between the means of P and S, $(60-56=4)$, and a variance equal to the sum of the variances of P and S, $(5^2+9.5^2=10.74^2)$. The probability of depletion in this formulation is $\Pr(D>0)$, which can be easily calculated to be 64.34 percent.

These interpretations of the uncertainty expressed in the workshop report (SWFC, 1976) led to the conclusion that there were better than six chances in ten that the eastern spinner dolphin population was below the lower limit of the optimum sustainable population range. Of course, a probability distribution from each of the workshop participants could have been obtained and combined by various expert resolution techniques. As one input to the depletion determination, however, the above interpretation of the collective uncertainty seemed appropriate. It avoided the need to say precisely that the lower level of OSP, for example, was at 50 percent, 60 percent, or any other point in the range when actual knowledge simply did not justify the choice of a single, precise value.

The Policy Determination

Once this probability was established, the policy question had to be faced as to whether 60 percent was a sufficiently high chance of depletion to require such a declaration. The U.S. District Court had explicitly characterized the approach which must be employed in discharging marine mammal obligations: "The interests of the marine mammals come first under the statutory scheme, and the interests of the [tuna fishing] industry, important as they are, must be served only after protection of the animals is assured" (Richey, 1976). While the determination may have been less clear if the probability of depletion was, say, 20 percent, given the legal constraints, the 60 percent chance was high enough to be quite in line with the ultimate declaration of depletion.

Conclusion

This particular example, which contains the complicating factors of expert disagreement and poor data, illustrates the promising use of a method for specifying uncertain beliefs and drawing inferences from them. In this case, the Act had stipulated that the marine mammals must be kept in the range of their "optimum sustainable populations." For marine fisheries generally, Federal law now requires that "Conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery" (U.S. Code, 1976). It is clear that, especially under these new regimes, similar determinations under uncertain conditions will be required. In the many difficult decisions which no doubt lie ahead in marine resource management, extension of these probabilistic techniques may help to clarify otherwise fuzzy situations.

Acknowledgments

I would like to thank William Aron for his explanations of the problem and for continual encouragement; Douglas Chapman for valuable suggestions and extensions to the basic approach; Brian Rothschild, Ronald Howard, and Richard Hennemuth for reviewing the work in its early stages; and Robert White for suggesting and supporting this venture.

Literature Cited

Crutchfield, J. A. 1972. Economic and political objectives in fishery management. *In* B. J. Rothschild (editor), World fisheries policy, p. 74-89. Univ. Wash. Press, Seattle.

Cushing, D. H. 1974. A link between science and management in fisheries. Fish. Bull., U.S. 72:859-864.

de Finetti, B. 1972. Probability, induction and statistics. John Wiley and Sons, Lond.

Jeffreys, H. 1961. Theory of probability. Charendon, Oxford.

Larkin, P.A. 1972. A confidential memorandum on fisheries service. *In* B. J. Rothschild (editor), World fisheries policy, p. 189-197. Univ. Wash. Press, Seattle.

National Marine Fisheries Service. 1975. Fisheries of the United States, 1974. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Curr. Fish. Stat. 6700, 98 p.

Raiffa, H. 1968. Decision analysis: Introductory lectures on choices under uncertainty. Addison-Wesley, Reading, 309 p.

Richey, C. R. 1976. U.S. District Court of Appeals, C.A. 75-0227, at 22.

Savage, L. J. 1954. Foundations of statistics. John Wiley, N.Y., 294 p.

SWFC. 1976. Report of the workshop on stock assessment of porpoises involved in the eastern tropical Pacific tuna fishery. Natl. Mar. Fish. Serv., Southwest Fish. Cent. Admin. Rep. LJ-76-29.

U.S. Code. 1972. Marine Mammal Protection Act of 1972. 16 U.S.C. 1361 et seq. University of Washington. 1976. 1975 Research in fisheries. Annu. Rep. Coll. Fish., p. 9. Univ. Wash., Seattle.

_____. 1976. Fishery Conservation and Management Act of 1976. 16 U.S.C. 1851.

von Mises, R. 1941. On the foundations of probability and statistics. Ann. Math. Stat., 12.

Spore Structure of *Minchinia chitonis*

S. J. BALL

ABSTRACT— The salient features of the fine structure of the spore of Minchinia chitonis *(Lankester, 1885) Labbé, 1896 are reviewed. The morphological characteristics are similar to those of the spores of other members of the family Haplosporidiidae, particularly the hinged operculum covering the anterior orifice, the "spherule" and the haplosporosomes.*

Introduction

The genus *Minchinia* was established by Labbé (1896) for a haplosporidian parasite of the chiton, *Lepidochitona cinereus.* The parasite, originally named *Klossia chitonis* by Lankester in 1885, is the type species (Sprague, 1963). *Minchinia chitonis* was the object of special studies by Pixell-Goodrich (1915), Debaisieux (1920), and King (1926) and has recently been reexamined by Ball and Neville (1979) and Ball (1980). This paper briefly reviews the information about the structure of the spore of this parasite, since the fine structural investigations have been directed toward this stage in the life cycle rather than the developmental stages.

The impetus to study the ultrastructure of the haplosporidia was the discovery of the pathogenicity of *H. costale* (Andrews et al., 1962; Wood and Andrews, 1962) and *H. nelsoni* (Haskin et al., 1966) to the oyster, *Crassostrea virginica.* The history of these oyster diseases has been reviewed by Andrews (1979). It is to Ormières and de Puytorac (1968), Perkins (1968, 1969), and Rosenfield et al. (1969) that we owe our first clear understanding of the morphology of the spores of *Minchinia* spp. and their similarity in structure. Electron microscope studies have revealed a number of new structures which help to confirm the interrelation of the genus *Minchinia* and other genera within the class Stellatosporea Sprague, 1979, formerly called Haplosporea.

Materials and Methods

Infected chitons were collected from the Plymouth area. For light microscopy, infected digestive gland was fixed in aqueous Bouin's solution and stained with Mallory's Triple stain. For electron microscopy, small pieces of infected digestive gland and foot were fixed in 2.5 percent (volume/volume) glutaraldehyde in 0.1M sodium cacodylate buffer at pH 7.2 for 2 hours at 4°C and processed as previously described (Ball, 1980).

Results

The basic structure and organelles of the spore *M. chitonis* as revealed by electron microscopy are depicted in Figure 1.

The spores are oval with a flattened pole covered by a hinged lid which rests on a circumferential flange of the spore wall (Fig. 2, 3, 6). The mature spores are remarkably uniform in size measuring 9.0-11.0 μm in length and 6.0-8.0 μm in width. Heavily infected chitons can be diagnosed macroscopically by areas of brown coloration on the foot and gills due to aggregates of sporocysts containing mature spores.

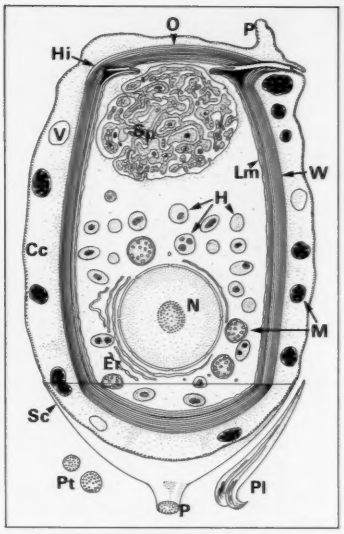

Figure 1.—Diagrammatic representation of the spore of *M. chitonis.*

In section, the smooth resistant laminated wall of the spore appears to be of uniform thickness of approximately 300 nm (Fig. 4). The outer cytoplasmic envelope contains mitochondria in the maturing spore and is strengthened by short microtubule-like filaments (Fig. 6). The extraspore cytoplasm is extended at both the poles to produce two long projections (Pixell-Goodrich, 1915; Debaisieux, 1920; Ball and Neville, 1979).

The nucleus of the spore is typically eukaryotic with a two membrane envelope, nuclear pores, and a prominent nucleolus and the cytoplasm contains smooth endoplasmic reticulum, mitochondria, and ribosomes (Fig. 1, 4, 6). Close to the lid is the organelle identified by light microscopy and called the "spherule." Its fine structure is a twisted laminated double membrane or vesicular organelle (Fig. 5, 6) considered by Perkins (1968, 1969) and Rosenfield et al. (1969) to possibly represent a Golgi apparatus.

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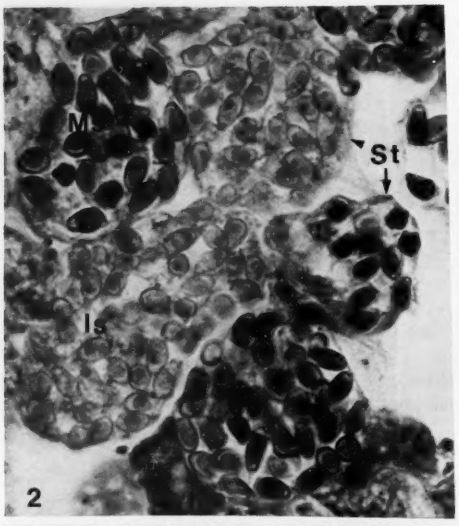
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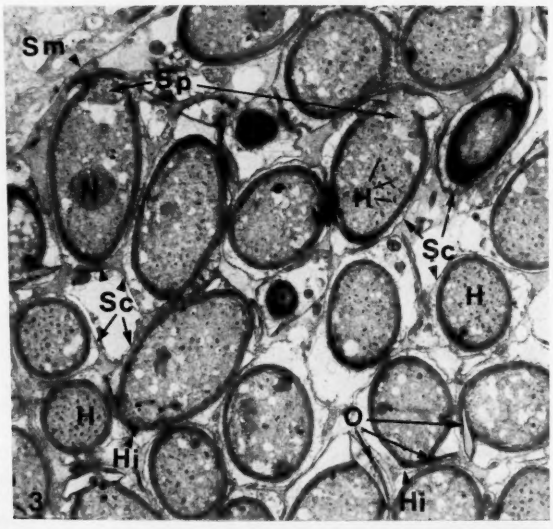
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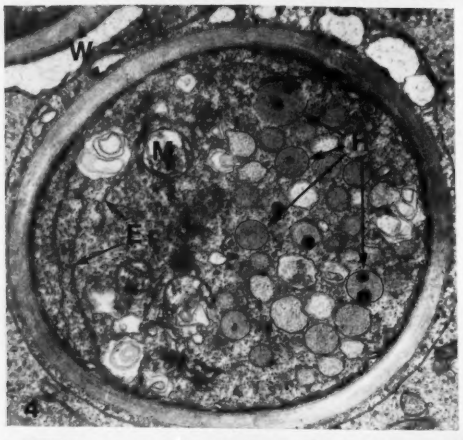
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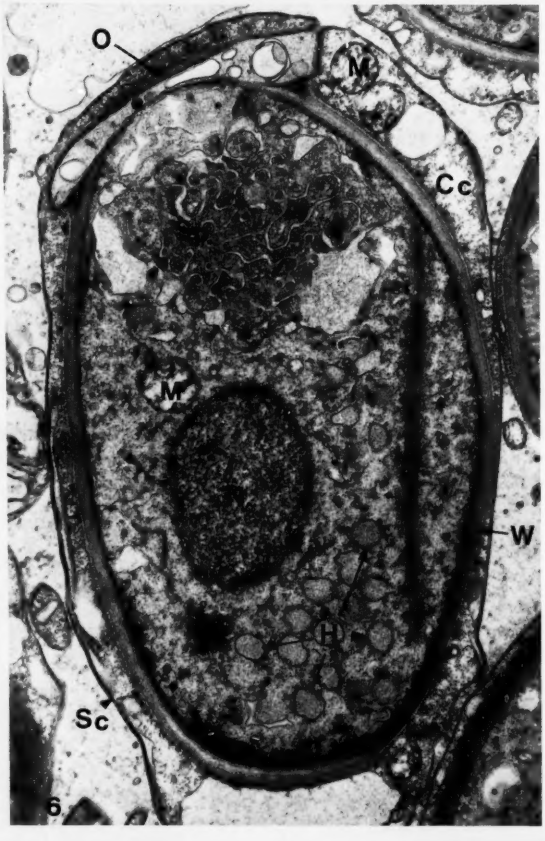
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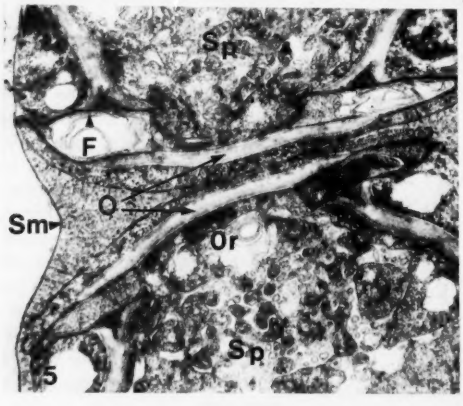
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Figure 2.—Light micrograph section of spores and sporocysts in the digestive gland of the chiton (600×).

Figure 3-6.—Electron micrographs of nearly mature spores of *M. chitonis.*

Figure 3.—Section of part of sporocyst showing developing spores each surrounded by a cytoplasmic capsule (3,000×).

Figure 4.—Cross section showing haplosporosomes and endoplasmic reticulum (15,600×).

Figure 5.—Sagittal section through anterior region showing lids, flanges, and sperules (18,000×).

Figure 6.—Slightly oblique longitudinal section to show haplosporosomes, spherule, and capsule (16,000×).

Abbreviations used in labelling. Cytoplasm of spore capsule (Cc); endoplasmic reticulum (Er); flange (F); haplosporosomes (H); hinge (Hi); immature spores (Im); limiting membrane of spore cytoplasm (Lm); mitochondrion (M); mature spores (Ms); nucleus (N); operculum (O); orifice of spore (Or); projection (P:t = transverse, l = longitudinal); spore capsule (Sc); sporocyst membrane (Sm); spherule (Sp); sporocyst (St); vacuole (V); wall (W).

Haplosporosomes (Perkins, 1971) are a constant feature scattered throughout the cytoplasm of the maturing (Fig. 3, 4, 6) and mature spore. They are electron pale vesicles often containing a single or occasionally up to three osmiophilic core(s). In section, the profiles of the haplosporosomes were either spherical, with a diameter ranging from 250 to 583 nm ($\bar{x}$ = 373 nm; n = 50), or oblate spheroid with a length from 267 to 563 nm ($\bar{x}$ = 413 nm; n = 50) and a width range of 233 to 444 nm ($\bar{x}$ = 329 nm; n = 50).

Discussion

In the last 12 years, studies of the fine structure of the Stellatosporea, particularly of the spores, have produced a number of new findings and advances in the knowledge of this group. Although the haplosporidian cell has many organelles similar to those in other cells, it has certain ultrastructural characteristics that distinguish it from other protozoans. These typical fine structural features have so far been found predominantly in the spore stage and are the operculum, "spherule," and haplosporosomes. The discovery of these fine structures and organelles resulted in their characteristics being used to reinforce the systematic position of this group of protozoans and as a basis for determining the relationship of various genera. The close relationship between the genera *Minchinia, Urosporidium,* and *Haplosporidium* has been established (Perkins, 1979) and the order Haplosporida to which they belong has been renamed Balanosporida by Sprague (1979).

Although the spore of *M. chitonis* is similar in its fine structure to the spores of other balanosporidans, the characteristic which distinguishes it from all but *M. armoricana* found in *Ostrea edulis* by van Banning (1977) is its two long extensions of the extraspore cytoplasm. In addition, both these parasites color the host brown when the spores are present in large numbers.

In 1963, Sprague reestablished the genus *Minchinia* and transferred several species to it from the genus *Haplosporidium.* He pointed out in 1970 that the electron microscope studies on the development of the spores of some members of these two genera had shown a similarity between them which invalidated his criteria for distinguishing them on the difference of the origin of the lids. In 1978, he reaffirmed an earlier suggestion (Sprague, 1970) and transferred the species with spores without projections (tails) to the genus *Haplosporidium.* This leaves only two species in the genus *Minchinia,* namely *M. armoricana* and *M. chitonis,* presumably defined as balanosporidans of the family Haplosporidiidae having spores with both orifice and operculum and two projections from the extraspore cytoplasm.

The mechanism of wall formation has not yet been determined and the significance of the wall ornamentation and the two projections of the wall is not known. Perkins (1979) pointed out that in the *Minchinia* spp. which he has examined the extraspore cytoplasm disperses leaving the spore surrounded by threads or ribbons. He made the interesting suggestion that the substructure of the wall ornaments might be species specific. The microtubule-like filaments seen in the extraspore cytoplasm of *M. chitonis* have not been recorded from other haplosporidans, but dispersal of the cytoplasm revealing this ornamentation has not so far been observed.

Minchinia chitonis appears to be host specific and is found in various organs and tissues of *L. cinereus* where it causes displacement of cells and destruction by volume alone. However, there is little obvious evidence of pathogenicity although the reproductive potential of infected hosts may be adversely affected. The many unanswered questions concerning *M. chitonis* are the same as those for the other balanosporidans, the main one being the elucidation of the life cycle with particular reference to the infectivity of the spore and its transmission.

Literature Cited

Andrews, J. D. 1979. Oyster diseases in Chesapeake Bay. *In* F. O. Perkins (editor), Haplosporidian and haplosporidian-like diseases of shellfish. Mar. Fish. Rev. 41(1-2):45-53.

_____, J. L. Wood, and H. D. Hoese. 1962. Oyster mortality studies in Virginia: III. Epizootiology of a disease caused by *Haplosporidium costale,* Wood and Andrews. J. Insect Pathol. 4:327-343.

Ball, S. J. 1980. Fine structure of the spores of

Minchinia chitonis (Lankester, 1885), Labbé, 1896 (Sporozoa: Haplosporida), a parasite of the chiton, *Lepidochitona cinereus.* Parasitology 81:169-176.

_____, and J. E. Neville, 1979. *Minchinia chitonis* (Lankester, 1885) Labbé, 1896, a haplosporidian parasite of the chiton, *Lepidochitona cinereus.* J. Moll. Stud. 45:340-344.

Debaisieux, P. 1920. *Haplosporidium (Minchinia) chitonis* Lank., *Haplosporidium nemertis,* nov. sp., et le groupe des Haplosporidies. La Cellule 30:291-311.

Haskin, H. H., L. A. Stauber, and J. A. Mackin. 1966. *Minchinia nelsoni* n.sp. (Haplosporida, Haplosporidiidae): causative agent of the Delaware Bay oyster epizoötic. Science (Wash., D.C.) 153:1414-1416.

King, S. D. 1926. Cytological observations on *Haplosporidium (Minchinia) chitonis.* Q. J. Microsc. Sci. 70:147-158.

Labbé, A. 1896. Recherches zoologiques, cytologiques et biologiques sur les coccidies. Arch. Zool. Exp. Gen. 4:517-654.

Lankester, E. R. 1885. Protozoa. *In* Encyclopaedia Britannica, 9th ed., p. 830-866.

Ormières, R., and P. de Puytorac. 1968. Ultrastructure des spores de l'haplosporidie *Haplosporidium ascidiarum* endoparasite due tunicier *Sydnium elegans* Giard. C. R. Acad. Sci., Ser. D., Paris 266:1134-1136.

Perkins, F. O. 1968. Fine structure of the oyster pathogen *Minchinia nelsoni* (Haplosporida, Haplosporidiidae). J. Invertebr. Pathol. 10:287-305.

_____. 1969. Electron microscope studies of sporulation in the oyster pathogen, *Minchinia costalis* (Sporozoa: Haplosporida). J. Parasitol. 55:897-920.

_____. 1971. Sporulation in the trematode hyperparasite *Urosporidium crescens* De Turk, 1940 (Haplosporida: Haplosporidiidae) - an electron microscope study. J. Parasitol. 57:9-23.

_____. 1979. Cell structure of shellfish pathogens and hyperparasites in the genera *Minchinia, Urosporidium, Haplosporidium,* and *Marteilia*—taxonomic implications. *In* F. O. Perkins (editor), Haplosporidian and haplosporidian-like diseases of shellfish. Mar. Fish. Rev. 41(1-2):25-37.

Pixell-Goodrich, H. L. M. 1915. *Minchinia:* a haplosporidian. Proc. Zool. Soc. Lond. 1915: 445-457.

Rosenfield, A., L. Buchanan, and G. B. Chapman. 1969. Comparison of the fine structure of spores of three species of *Minchinia* (Haplosporida, Haplosporidiidae). J. Parasitol. 55:921-941.

Sprague, V. 1963. Revision of genus *Haplosporidium* and restoration of genus *Minchinia* (Haplosporidia, Haplosporidiidae). J. Protozool. 10:263-266.

_____. 1970. Recent problems of taxonomy and morphology of Haplosporidia. [Abstr. 602] J. Parasitol. 56 (4, Sec. 11. Part 1): 327-328.

_____. 1978. Comments on trends in research on parasitic diseases of shellfish and fish. Mar. Fish. Rev. 40(10):26-30.

_____. 1979. Classification of the Haplosporidia. *In* F. O. Perkins (editor), Haplosporidian and haplosporidian-like diseases of shellfish. Mar. Fish. Rev. 41(1-2):40-44.

van Banning, P. 1977. *Minchinia armoricana* sp. nov. (Haplosporida), a parasite of the European flat oyster, *Ostrea edulis.* J. Invertebr. Pathol. 30:199-206.

Wood, J. L., and J. D. Andrews. 1962. *Haplosporidium costale* (Sporozoa) associated with a disease of Virginia oysters. Science (Wash., D.C.) 136:710-711.

Histamine Formation and Honeycombing During Decomposition of Skipjack Tuna, *Katsuwonus pelamis*, at Elevated Temperatures

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ABSTRACT—Decomposition was studied in skipjack tuna, Katsuwonus pelamis, *caught in Hawaiian waters. Fresh skipjack tuna tissue was practically devoid of histamine (about 0.1 mg/100 g tuna), but this compound formed readily when whole fish were incubated at moderate and elevated temperatures. Histamine formation was optimum at 37.8°C (100°F) and was dependent upon microbial activity. Honeycombing, a condition characterized by the destruction of connective tissue, was evaluated in incubated skipjack tuna and had an optimum temperature of 32.2°C (90°F). Honeycomb formation occurred in the presence of antibiotics that inhibited microbial activity and histamine formation.*

Introduction

Most fish decompose rapidly unless some method of preservation is instituted soon after they are caught. One major cause of decomposition is the varied reservoir of spoilage bacteria contained by the fish and present in the environment. An extensive literature is available on the distribution and classification of the spoilage organisms as well as the natural microflora of many kinds of marine fish (Griffiths, 1937; Tomiyasu and Zenitani, 1957; Shewan, 1961, 1962; Shewan and Hobbs, 1967; Shewan, 1977). Considerable interest has been directed toward the decomposition of scombroid fish (family Scombridae), particularly in mackerel, sardines, and several types of tuna where spoilage is associated with high levels of histamine in the fish (Williams, 1954; Hillig, 1956a; Tomiyasu and Zenitani, 1957; Kimata, 1961; Arnold and Brown, 1978).

Fresh tuna and other scombroid fish are essentially devoid of histamine (Geiger et al., 1944; Geiger, 1948; Hardy and Smith, 1976; Fernandez-Salguero and Mackie, 1979) but they contain substantial amounts of free histidine, exceeding 1 g per 100 g of skipjack tuna tissue (Lukton and Olcott, 1958). It is generally agreed that the histamine found in scombroid fish is formed by bacteria that can decarboxylate histidine (Shifrine et al., 1959; Kimata, 1961; Ferencik, 1970; Edmunds and Eitenmiller, 1975; Taylor et al., 1977; Arnold and Brown, 1978; Omura et al., 1978; Taylor et al., 1979). A variety of such bacteria, particularly Enterobacteriaceae, recovered from spoiled scombroid fish are considered to be responsible for their decomposition and the elevated histamine observed (Geiger, 1955; Mossel, 1968; Lerke et al., 1978; Arnold and Brown, 1978).

Because histamine is heat stable, some workers have suggested that the histamine content would be suitable as a quantitative index of prior microbial spoilage in canned tuna (Geiger, 1944; Williams, 1954; Ferencik et al., 1961; Ienistea, 1973). At present, histamine evaluation is used voluntarily as a routine quality control procedure by most of the tuna canning industry (Lieber and Taylor, 1978).

Many other indices have been employed to measure spoilage in fish (Tomiyasu and Zenitani, 1957; Lassen, 1965; Martin et al., 1978), including sensory assessments (Shewan et al., 1953; Burt et al., 1975), the formation of compounds such as volatile acids (Hillig, 1954, 1956a), trimethylamine (Farber and Lerke, 1961; Martin et al., 1978), hypoxanthine (Burt, 1977; Martin et al., 1978), volatile reducing substances (Farber and Lerke, 1961) and ethanol (Lerke and Huck, 1977) and high bacterial counts (Tomiyasu and Zenitani, 1957; Farber and Lerke, 1961; Lerke et al., 1965; Martin et al., 1978). For a number of years the tuna canning industry also has used honeycomb formation, a condition caused by the breakdown of connective tissue (Hillig, 1956b; Otsu, 1957; Lassen, 1965; Tanikawa, 1971; Finch and Courtney, 1976), as an index of decomposition.

The present investigation concerns the relationship between histamine formation and decomposition in skipjack tuna, *Katsuwonus pelamis*, and is part of a broader study of spoilage in tuna caught near the Hawaiian Islands. This study shows that the optimum temperature for histamine formation in skipjack tuna is 37.8°C (100°F), and that the optimum for honeycombing is 32.2°C (90°F). Moreover, histamine formation is dependent upon microbial activity, but honeycombing can occur in the presence of antibiotics that are inhibitory to microbial growth.

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Materials and Methods

Fish

Skipjack tuna, each weighing about 1.8-2.3 kg (4-5 pounds), were caught in nearby ocean waters (mean temperature about 75°F or 24°C), delivered live to the National Marine Fisheries Service research facility at Kewalo Basin on Oahu, Hawaii, and held for about 12-18 hours in storage tanks fed by recirculating fresh seawater. The fish were removed from the tanks, allowed to expire by being kept for 5-10 minutes in ice-chilled seawater, and transported in crushed ice to the Department of Food Science and Human Nutrition at the University of Hawaii for use in experiments. Normally about 1 hour elapsed between expiration of the fish and the initiation of laboratory incubations. These precautions prevented any undesired postmortem spoilage changes during handling before incubation.

Incubation

The fish were placed in separate polyethylene bags containing 4-5 l of filtered fresh seawater and held for the desired time in a temperature-controlled water bath.

Precooking

Following incubation, the tuna were eviscerated and decapitated, and each side was cut into sections (Fig. 1). The number of sections obtained depended upon size; fish weighing 1.8-2.3 kg (4-5 pounds) yielded 5 sections, and smaller fish could be divided into 3-4 sections. The sectioned fish were given a low-pressure steam precook of 15 minutes at 104.4°C (220°F) in a home-style pressure cooker. In commercial processing, the purpose of precooking is to coagulate the flesh protein to aid removal of the skin and bones during cleaning and to facilitate cutting the loins into pieces suitable for canning (Lassen, 1965; Bacon, 1971; Finch and Courtney, 1976).

Honeycombing

After precooking, the tuna were cooled thoroughly, and honeycomb formation was evaluated by two experienced individuals using a five-point scale based on the degree and distribution of honeycombing throughout the fish (Table 1). Honeycombing ratings represent mean evaluation scores taken from duplicate experiments for each set of conditions tested. Honeycombing is seen mainly as pitted sponge-like deposits between loins and often as indentations of the loin surfaces. In cases of advanced honeycombing, the connective tissue appears vacuolated, and transverse sections of the loin resemble a vacant honeycomb (Hillig, 1956b; Otsu, 1957).

Table 1.—Scale for quantitative evaluation of honeycombing in skipjack tuna.

Score[1]	Description
0	No honeycombing in any part of fish
1	Very slight honeycombing in belly, dorsal line or blood meat but not in loins
2	Slight honeycombing in belly, dorsal line, blood meat and in parts of anterior loins
3	Moderate honeycombing in belly, entire dorsal line, blood meat and some loin sections
4	Moderate-to-extensive honeycombing in belly, entire dorsal line and blood meat, and moderate honeycombing in all loins
5	Extensive honeycombing in all parts of fish, including the loins. Connective tissue has a sponge-like appearance

[1]Intermediate scores (e.g., 0.5, 1.5, etc.) can be assigned where appropriate.

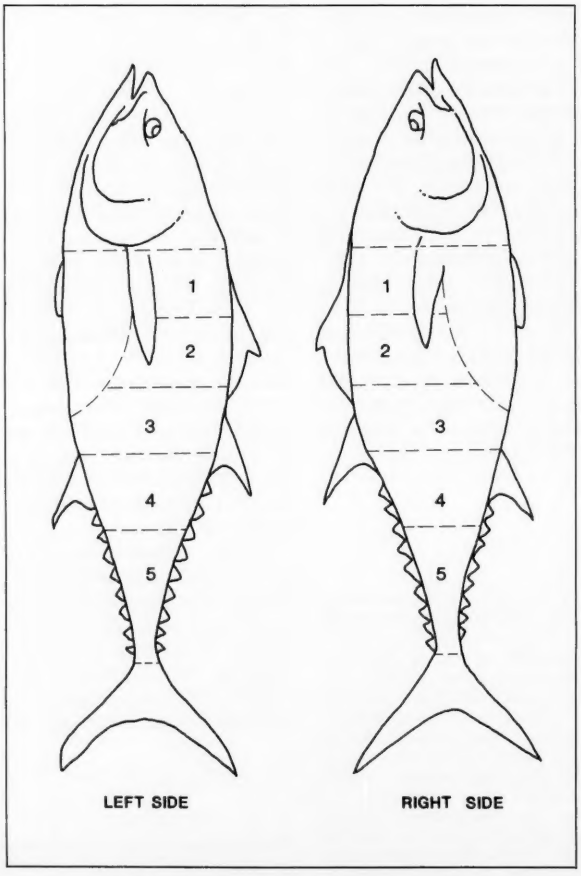

Figure 1.—Numbering scheme for identification of fish sections.

Histamine Content of Tuna

Precooked fish sections were cleaned, comminuted twice in a household meat grinder and analyzed for histamine as described by Staruszkiewicz et al. (1977) and in AOAC (1975) (Sections 18.060-18.062). Ten g of each section were extracted with methanol, passed through an anion exchange resin to remove interfering compounds, derivatized with o-phthalaldehyde, and the histamine measured fluorometrically. The histamine content reported for each section of fish represents the mean value of eight estimations taken from duplicate determinations by two technicians for both sides of the section.

Because histamine levels were not uniform for all sections of the same fish (see Tables 3, 4), it was difficult sometimes to compare tuna that had been given different treatments. However, this problem was overcome by considering each fish as a single system whose histamine load could be expressed by its composite histamine content. Composite histamine concentrations (mg/100 g tuna) reported for some fish (see Tables 4, 7) are calculated as |the total amount (mg) of histamine present in all fish sections/total weight (g) of all fish sections| × 100.

Microbiological Examination

Microbial counts were made with tissue taken from tuna section 2. Samples were diluted with sterile 0.1 percent peptone (BBL) and inoculated on trypticase soy agar (BBL); colonies were counted after incubation for 2-3 days at 37°C (98.6°F). Gram stains of tuna tissue and seawater incubation liquid also were examined microscopically for the presence of microorganisms.

Antibiotics

The inhibitory effect of antibiotics on histamine formation and honeycombing was studied by incubating tuna in seawater containing 160 units per ml of Penicillin G (Calbiochem[1], Los Angeles) and 0.1 mg per ml Tetracycline hydrochloride (A. H. Robbins, Richmond, Va.). Fish were incubated for 24 hours at 35°C (95°F), a temperature that is intermediate between the optima for histamine formation and honeycombing in skipjack tuna.

Preliminary experiments revealed that slight histamine formation occurred in areas of the fish that had not been reached by antibiotics, especially in section 1. To facilitate penetration of the antibiotics to all tuna tissue, the gills and viscera were removed and the fish severed between sections 2 and 3. Each piece was put in a separate polyethylene bag containing seawater plus antibiotics and placed in the water bath. After incubation for 24 hours at 35°C (95°F), analyses were conducted for histamine, honeycombing, and the presence of microorganisms.

Results

Histamine Formation

Fresh skipjack tuna contained essentially no free histamine; in most cases only about 0.1 mg/100 g was present in any fish section (Table 2).

Table 3 shows the effect of incubation temperature on histamine formation in skipjack tuna. Very little histamine had formed in 24 hours at 21.1°C (70°F) and below, but at 23.9°C (75°F) a small amount of histamine was present throughout most of the fish, with a substantial level (74.5 mg/100 g) in the anteriormost section 1. The optimum temperature for histamine production was 37.8°C (100°F) where levels of 472 to 643 mg/100 g were found in all sections. At higher temperatures, histamine formation decreased, and at 43.3°C (110°F) and above the tuna tissue underwent extensive deterioration, but very little histamine was present.

A characteristic pattern of histamine distribution was observed in this study. The earliest indication of histamine occurred in fish section 1, and the histamine level remained highest in that section throughout incubation. The other fish sections had less histamine, arranged in a gradually decreasing gradient toward the posterior end of the fish. The belly flaps (not included in Tables 2 and 3) were exceptions to this gradient and usually had histamine levels that were nearly as high as in section 1.

Table 4 shows the rates of histamine formation during incubation at the optimum temperature, 37.8°C (100°F). A lag period of 6-12 hours elapsed before significant histamine production was detected in section 1; at 18 hours considerable histamine was found in most sections, with greater concentrations occurring in the anterior part of the fish. After 24 hours the histamine level was very high throughout the fish, ranging from 261 to 481 mg/100 g in each section. Assessment of histamine formation from composite histamine values given in the righthand column of Table 4 also shows an initial 12-hour lag and the changing production rate that followed. Therefore, composite histamine values will be used below to express histamine formation in terms of the entire fish (see Table 7).

Table 2.—Histamine content of fresh skipjack tuna.

Trial no.	Histamine (mg/100 g tuna) and fish section number[1] 1	2	3	4	5
1	0.06	0.07	0.06	0.08	0.09
2	0.12	0.11	0.09	0.12	0.06
3	0.11	0.10	0.10	0.10	0.07
4	0.14	0.17	0.08	0.09	0.13
5	0.23	0.17	0.19	0.11	0.09
Average	0.13	0.12	0.10	0.10	0.09

[1]From Figure 1.

Table 3.—Histamine content of skipjack tuna incubated 24 hours at various temperatures.

Temp. °C	°F	Histamine (mg/100 g tuna) and fish section number[1] 1	2	3	4	5
15.6	60	0.21	0.18	0.17	0.18	0.15
21.1	70	2.80	1.05	0.96	0.99	0.84
23.9	75	74.5	6.50	3.25	2.46	4.95
26.7	80	102	6.99	1.59	4.51	2.90
29.4	85	114	72.5	56.0	52.2	71.5
32.2	90	248	—[2]	41.3	—[2]	45.2
35.0	95	369	241	84.4	59.1	59.6
37.8	100	643	540	472	479	534
40.6	105	354	236	—[3]	185	255
43.3	110	1.47[4]				
48.9	120	0.62[4]				

[1]From Figure 1.
[2]Very small fish; only 3 sections.
[3]Small fish; 4 sections.
[4]Sectioning was not possible because the fish disintegrated during incubation. Histamine estimations were made from composites of each side of the fish.

[1]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

Table 4.—Histamine formation in skipjack tuna incubated at 37.8°C (100°F).

Time (h)	Histamine (mg/100 g tuna) and fish section number[1] 1	2	3 (hours)	4	5	Composite histamine[2] (mg/100 g tuna)
0	0.13	0.12	0.10	0.10	0.09	0.11
6	0.47	0.43	0.51	0.52	0.55	0.50
12	42.1	6.13	3.69	3.91	6.72	15.1
18	213	49.5	21.1	20.7	31.7	67.3
24	481	367	424	261	289	343

[1]From Figure 1.

[2]Composite histamine = $\frac{\text{Sum of histamine in all sections (mg)}}{\text{Total weight of fish sections (g)}} \times 100$.

Table 5.—Honeycomb formation in skipjack tuna incubated 24 hours at various temperatures.

Temperature °C	°F	Honeycombing score[1]	Temperature °C	°F	Honeycombing score[1]
15.6	60	0	35.0	95	3.0-4.0
21.1	70	0.5	37.8	100	3.0
23.9	75	0.5	40.6	105	1.5
26.7	80	2.0	43.3	110	—[2]
29.4	85	1.5-2.0	48.9	120	—[2]
32.2	90	4.0			

[1]See Table 1.

[2]Fish disintegrated; honeycomb evaluation impossible.

Samples of loin tissue taken from tuna incubated 18 and 24 hours (Table 4) had total microbial counts of 2.5×10^5 and 2.8×10^5/g, respectively. Cultures isolated from tuna incubated for 24 hours were mainly gram-negative, facultatively anaerobic rods (Yoshinaga, 1979) and will be the subject of another manuscript.

Honeycombing

Table 5 shows the effect of temperature on honeycombing in skipjack tuna. Honeycomb formation was negligible after 24 hours at temperatures below 26.7°C (80°F), but it increased as higher incubation temperatures were used and was optimum at about 32.2°C (90°F). At 43.3°C (110°F) and above, disintegration of the fish tissue prevented quantitative evaluation of honeycombing.

Table 6 shows the rate of honeycombing at the optimum temperature, 32.2°C (90°F). Honeycombing proceeded without any apparent lag and increased gradually until 22.5 hours when appreciable decomposition was noted. At 30 hours, breakdown of the connective tissue was widespread, and at 37.5 hours destruction was complete.

Effect of Antibiotics

Table 7 shows the effect of penicillin and tetracycline on honeycombing and histamine formation in skipjack tuna held at 35°C (95°F). When an intact fish was incubated for 24 hours, ample histamine (164 mg/100 g) was formed and moderate honeycombing (score = 3.0) occurred. After removal of the gills and viscera, the histamine level was reduced by about one-half (to 75.6 mg/100 g) but honeycombing was unaffected (score = 3.5). However, when uptake of the antibiotics was improved by cutting the fish between sections 2 and 3, histamine production was essentially insignificant (1.62 mg/100 g). Honeycombing, on the other hand, was fairly extensive (score = 3.5-4.0) after 24 hours and apparently not inhibited by the antibiotics.

Microbial counts from the loin tissue and microscopic examination of the seawater showed that few microorganisms were present, and that microbial growth had not occurred in the presence of the antibiotics.

Table 6.—Honeycomb formation in skipjack tuna incubated at 32.2°C (90°)F.

Time in hours	Honeycombing score[1]	Time in hours	Honeycombing score[1]
0	0	22.5	4.0-4.5
7.5	1.0-1.5	30	4.5-5.0
15	1.5-2.0	37.5	5.0

[1]See Table 1.

Table 7.—Effect of antibiotics on honeycombing and histamine formation in skipjack tuna incubated 24 hours at 35°C (95°F).

Treatment	Antibiotics[1]	Composite histamine[2] (mg/100 g tuna)	Honeycombing[3] score
Whole fish	None	164	3.0
Fish eviscerated and degilled	None	75.6	3.5
Fish eviscerated, degilled and separated between sections 2 and 3	Yes	1.62	3.5-4.0

[1]Penicillin, 160 units/ml; tetracycline hydrocholoride, 0.1 mg/ml.

[2]Composite histamine = $\frac{\text{Sum of histamine in all sections (mg)}}{\text{Total weight of fish sections (g)}} \times 100$.

[3]See Table 1.

Discussion

To study the relationship between histamine formation and decomposition it was necessary to determine how much histamine was present initially in fresh skipjack tuna. This study confirms previous observations that fresh scombroid fish contain very little free histamine (Geiger et al., 1944; Hillig, 1956a; Ferencik, 1970).

The effect of temperature on histamine formation in scombroid fish has been discussed in a number of publications (Kimata, 1961; Ienistea, 1973; Edmunds and Eitenmiller, 1975; Arnold and Brown, 1978; Lerke et al., 1978; Fernandez-Salguero and Mackie, 1979) but with little agreement on minimum, maximum, and optimum temperatures. Two major reasons for the inconsistencies are that different species of fish were studied and that variations occurred in fish handling before incubation. In this study we were fortunate to have an ample supply of live skipjack tuna available for experiments. Hence, the entire postmortem thermal history of each fish was known, and it was possible to study the effect of temperature under carefully controlled conditions.

Our study shows that the optimum temperature for histamine production in skipjack tuna is 37.8°C (100°F) and that, as others have reported, the hista-

mine is not uniformly distributed throughout the fish (Hillig, 1956a; Ienistea, 1973; Lerke et al., 1978). Inhibition by penicillin and tetracycline observed in this study also supports the widely held view that histidine decarboxylating bacteria are responsible for the presence of histamine in scombroid fish (Geiger et al., 1944; Tomiyasu and Zenitani, 1957; Shifrine et al., 1959; Kimata, 1961; Ferencik, 1970; Ienistea, 1973; Edmunds and Eitenmiller, 1975; Taylor et al., 1977; Arnold and Brown, 1978; Omura et al., 1978; Fernandez-Salguero and Mackie, 1979; Taylor et al., 1979) and that histamine is not formed physiologically by fish tissue under aseptic conditions (Geiger et al., 1944; Geiger, 1955; Ferencik, 1970; Fernandez-Salguero and Mackie, 1979).

The postmortem temperatures of decomposing scombroid fish usually are moderate; hence, honeycombing and histamine formation generally develop at slower-than-optimal rates under normal conditions. Occasionally, however, fish temperatures can become high, particularly in warm tropical waters and during prolonged exposure on the hot deck of the fishing vessel. In these instances, shorter times would be required for spoilage to become extensive.

Whether or not specific levels of histamine can be used to measure decomposition or serve as indices of quality in canned tuna has been discussed for a long time (Geiger, 1944; Hillig, 1954; Williams, 1954; Hillig, 1956a; Arnold and Brown, 1978). However, additional data showing the relationship of histamine level to reliable measures of tuna quality will be necessary before such quality standards are possible.

The results given in this study relative to honeycombing are significant for a number of reasons. First, this study has shown that the optimum temperature for honeycombing in skipjack tuna is slightly lower than it is for histamine formation. Second, incubations employing antibiotics showed that honeycombing could occur when microbial inhibitors were present, suggesting that breakdown of connective tissue collagen may result from proteolytic enzymes in the fish tissue. Because many degradative enzymes have been found in the lysosomes of other animals, it is tempting to speculate that collagenolytic enzymes in the lysosomes of skipjack tuna may be responsible for honeycombing. Considerable investigation would be needed to identify these enzymes and to determine their location. Moreover, it is possible that some of the proteolytic microorganisms present in scombroid fish may contribute to honeycombing under natural conditions. Third, we have employed a quantitative scale to evaluate honeycombing to compare the effect of different variables (e.g., temperature, time, etc.) on destruction of the connective tissue. We anticipate that changes can be made to improve the accuracy and usefulness of this scale for skipjack tuna as well as other tuna that are subject to honeycombing.

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Literature Cited

AOAC. 1975. Official Methods of Analysis, 12th ed., p. 315-317. Assoc. Off. Anal. Chem., Wash., D.C.

Arnold, S. H., and W. D. Brown. 1978. Histamine (?) toxicity from fish products. Adv. Food Res. 24:113-154.

Bacon, E. K. 1971. Quality control of ingredients used in tuna canning. *In* R. Kreuzer (editor), Fish inspection and quality control, p. 92-96. Fishing News (Books) Ltd., London.

Burt, J. R. 1977. Hypoxanthine: a biochemical index of fish quality. Process Biochem. 12(1):32-35.

_____, D. M. Gibson, A. C. Jason, and H. R. Sanders. 1975. Comparison of methods of freshness assessment of wet fish. Part I. Sensory assessments of boxed experimental fish. J. Food Technol. 10:645-656.

Edmunds, W. J., and R. R. Eitenmiller. 1975. Effect of storage time and temperature on histamine content and histidine decarboxylase activity of aquatic species. J. Food Sci. 40:516-519.

Farber, L., and P. Lerke. 1961. Studies on the evaluation of freshness and on the estimation of the storage life of raw fishery products. Food Technol. 15(4):191-196.

Ferencik, M. 1970. Formation of histamine during bacterial decarboxylation of histidine in the flesh of some marine fishes. J. Hyg., Epidemiol., Microbiol., Immunol. 14:52-60.

_____, V. Krcmery, and J. Kriska. 1961. Fish poisoning caused by histamine. J. Hyg., Epidemiol., Microbiol., Immunol. 5:341-348.

Fernandez-Salguero, J., and I. M. Mackie. 1979. Histidine metabolism in mackerel (*Scomber scombrus*). Studies on histidine decarboxylase activity and histamine formation during storage of flesh and liver under sterile and non-sterile conditions. J. Food Technol. 14:131-139.

Finch, R., and G. Courtney. 1976. The tuna industry. *In* M. E. Stansby (editor), Industrial fishery technology, p. 91-109. Robert E. Krieger Publ. Co., Inc., Huntington, N.Y.

Geiger, E. 1944. Histamine content of unprocessed and canned fish. A tentative method for quantitative determination of spoilage. Food Res. 9:293-297.

_____. 1948. On the mechanism of histamine formation. Arch. Biochem. 17:391-395.

_____. 1955. Role of histamine in poisoning with spoiled fish. Science (Wash., D.C.) 121:865-866.

_____, G. Courtney, and G. Schnakenberg. 1944. The content and formation of histamine in fish muscle. Arch. Biochem. 3:311-319.

Griffiths, F. P. 1937. A review of the bacteriology of fresh marine-fishery products. Food Res. 2:121-134.

Hardy, R., and J. G. M. Smith. 1976. The storage of mackerel (*Scomber scombrus*). Development of histamine and rancidity. J. Sci. Food Agric. 27:595-599.

Hillig, F. 1954. Individual volatile acids, succinic acid, and histamine as indices of decomposition in Atlantic "little tuna" (*Euthynnus alleteratus*). J. Assoc. Off. Agric. Chem. 37:927-931.

_____. 1956a. Volatile acids, succinic acid, and histamine as indices of decomposition in tuna. J. Assoc. Off. Agric. Chem. 39:773-800.

_____. 1956b. Note on honeycombing in decomposed tuna. J. Assoc. Off. Agric. Chem. 39:1015-1016.

Ienistea, C. 1973. Significance and detection of histamine in food. *In* B. C. Hobbs and J. H. B. Christian (editors), The microbiological safety of food, p. 327-343. Acad. Press, Lond.

Kimata, M. 1961. The histamine problem. *In* G. Borgstrom (editor), Fish as food. Vol. I. Production, biochemistry, and microbiology, p. 329-352. Acad. Press, N.Y.

Lassen, S. 1965. Tuna canning and the preservation of the raw material through brine refrigeration. *In* G. Borgstrom (editor), Fish as food. Vol. IV. Processing, part 2, p. 207-245. Acad. Press, N.Y.

Lerke, P. A., and R. W. Huck. 1977. Objective determination of canned tuna quality: identification of ethanol as a potentially useful index. J. Food Sci. 42:755-758.

_____, R. Adams, and L. Farber. 1965. Bacteriology of spoilage of fish muscle. III. Characterization of spoilers. Appl. Microbiol. 13:625-630.

_____, S. B. Werner, S. L. Taylor, and L. S. Guthertz. 1978. Scombroid poisoning. Report of an outbreak. West. J. Med. 129:381-386.

Lieber, E. R., and S. L. Taylor. 1978. Thin-layer chromatographic screening methods for histamine in tuna fish. J. Chromatogr. 153:143-152.

Lukton, A., and H. S. Olcott. 1958. Content of free imidazole compounds in the muscle tissue of aquatic animals. Food Res. 23:611-618.

Martin, R. E., R. J. H. Gray, and M. D. Pier-

son. 1978. Quality assessment of fresh fish and the role of the naturally occurring microflora. Food Technol. 43(5):188-192, 198.
Mossel, D. A. A. 1968. Bacterial toxins of uncertain oral pathogenicity. *In* H. D. Graham (editor), The safety of foods, p. 168-182. Avi Publ. Co., Inc., Westport, Conn.
Omura, Y., R. J. Price, and H. S. Olcott. 1978. Histamine-forming bacteria isolated from spoiled skipjack tuna and jack mackerel. J. Food Sci. 43:1779-1781.
Otsu, T. 1957. Development of "honeycombing" in Hawaiian skipjack tuna. Commer. Fish. Rev. 19:1-8.
Shewan, J. M. 1961. The microbiology of seawater fish. *In* G. Borgstrom (editor), Fish as food. Vol. I. Production, biochemistry, and microbiology, p. 487-560. Acad. Press, N.Y.
_____. 1962. The bacteriology of fresh and spoiling fish and some related chemical changes. *In* J. Hawthorn and J. M. Leitch (editors), Recent advances in food science. Vol. I. Commodities, p. 167-193. Butterworths, Lond.
_____. 1977. The bacteriology of fresh and spoiling fish and the biochemical changes induced by bacterial action. *In* P. Sutcliffe and J. Disney (editors), Proc. Conf. Handling, Processing and Marketing of Trop. Fish, p. 51-66. Tropical Products Institute, Lond.
_____, and G. Hobbs. 1967. The bacteriology of fish spoilage and preservation. Prog. Ind. Microbiol. 6:169-208.
_____, R. G. MacIntosh, C. G. Tucker, and A. S. C. Ehrenberg. 1953. The development of a numerical scoring system for the sensory assessment of the spoilage of wet white fish stored in ice. J. Sci. Food Agric. 4:283-298.
Shifrine, M., L. E. Ousterhout, C. R. Grau, and R. H. Vaughn. 1959. Toxicity to chicks of histamine formed during microbial spoilage of tuna. Appl. Microbiol. 7:45-50.
Staruszkiewicz, W. F., Jr., E. M. Waldron, and J. F. Bond. 1977. Fluorometric determination of histamine in tuna: development of method. J. Assoc. Off. Anal. Chem. 60:1125-1130.
Tanikawa, E. 1971. Marine products in Japan—size, technology and research. Koseisha-Koseikaku Company, Tokyo, 507 p.
Taylor, S. L., E. R. Lieber, and M. Leatherwood. 1978. A survey of histamine levels in commercially processed scombroid fish products. J. Food Qual. 1:393-397.
_____, L. S. Guthertz, M. Leatherwood, and E. R. Lieber. 1979. Histamine production by *Klebsiella pneumoniae* and an incident of scombroid fish poisoning. Appl. Env. Microbiol. 37:274-278.
Tomiyasu, Y., and B. Zenitani. 1957. Spoilage of fish and its preservation by chemical agents. Adv. Food Res. 7:41-82.
Williams, D. W. 1954. Report on chemical indices of decomposition in fish (histamine). J. Assoc. Off. Agric. Chem. 37:567-572.
Yoshinaga, D. H. 1979. Microbial formation of histamine in skipjack tuna (*Katsuwonus pelamis*). Master's Thesis, University of Hawaii, Honolulu, 52 p.

Physical Properties of Blue Shark Useful in Designing a Skinning Machine

D. E. BROWN, R. PAUL SINGH, R. E. GARRETT, and BARBARA KATZ

Introduction

Sharks are among the most ancient and notorious of the fishes living today in the world ocean. Despite their "man-eating" reputation, catching shark for human consumption is a long-standing and worldwide practice. A record 10.2 million kg (22.6 million pounds) of shark were landed by U.S. commercial fishermen in 1979 (NOAA, 1980).

Blue shark, *Prionace glauca,* found in abundance in the waters off southern California, is considered an underutilized food source. Further, blue sharks are considered a pest by most commercial and sport fishermen. They are often caught incidentally with squid, a main component of the blue shark diet. They are considered a migratory, pelagic species.

Longlining is one method used to catch blue sharks. The authors observed this technique (Fig. 1) aboard the commercial fishing vessel *JJ.* In this labor-intensive operation, over 250 hooks are baited and clipped to a stainless steel line. The line, set for up to 5 hours while the boat drifts on the open sea, takes blue sharks from 1.2 to 2.5 m (approximately 4-8 feet) in length. The line is then winched back aboard and the sharks are removed from the line, gaffed, and restrained manually on a gutting table. The tail is severed to bleed the shark and the fins are removed with a knife. The shark is then gutted and headed and the unskinned carcass is dropped into the hold and chilled with a cold saltwater spray. Then the longline is winched again and the next shark is removed from the line.

Commercial fishermen received $0.59-0.66/kg ($0.27-0.30/pound) in October 1980 for the unskinned blue shark carcasses at San Pedro, Calif. These are then sliced into fillets and each piece is skinned. It is estimated that 30-50 percent of the meat is lost when the shark steaks are skinned by the processor[1]. The fins, also valuable, are dried and shipped to the Orient for shark-fin soup.

Despite the unpopularity of shark meat in North America, members of the seafood industry feel there is a great need for a machine to skin blue shark[2]. A wider market for blue shark products is being sought. For example, if removed in one piece the skin is of value for making leather. The machine proposed to skin blue shark could aid its use for meat, fins, and hide and turn a former pest into a viable commercial fishery.

Design Parameters

Ocean Leather Corporation[3], Newark, N.J., has been converting shark skins into leather for shoes and other prestigious leather goods since 1922 (Brody, 1965). The required hide shape

[1] C. Christen, FV *JJ,* Terminal Island, Calif. Pers. commun., 1979.

[2] Gary, R. L., Sun Harbor Industries, San Diego, Calif. Pers. commun., 1979.

[3] Mention of trade names or commercial firms does not imply endorsement of the National Marine Fisheries Service, NOAA.

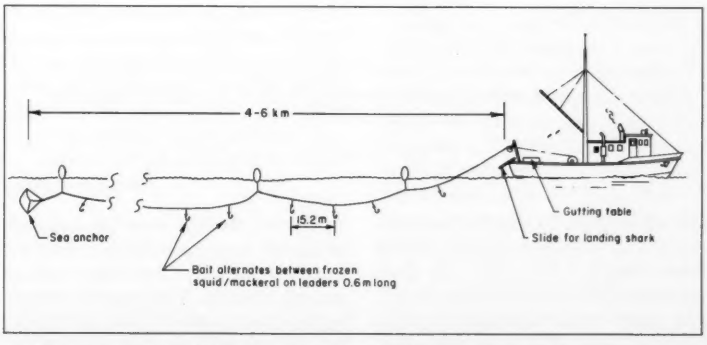

Figure 1.—Longline fishing method for blue shark as practiced on the commercial fishing vessel *JJ.*

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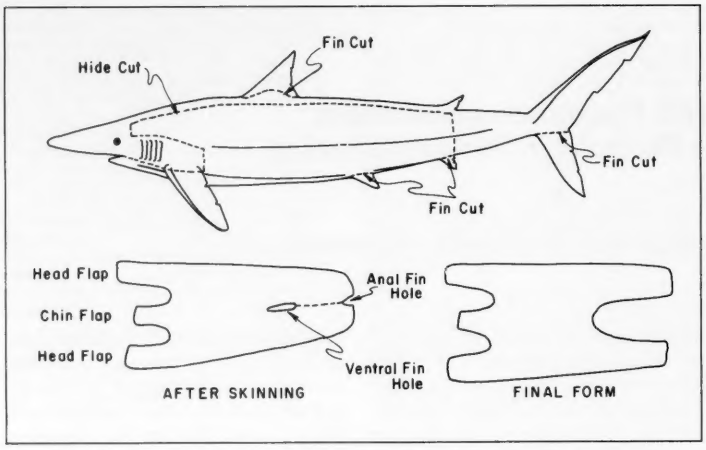


Figure 2.—Required form of blue shark hide after skinning (adapted from Ocean Leather Corp.).

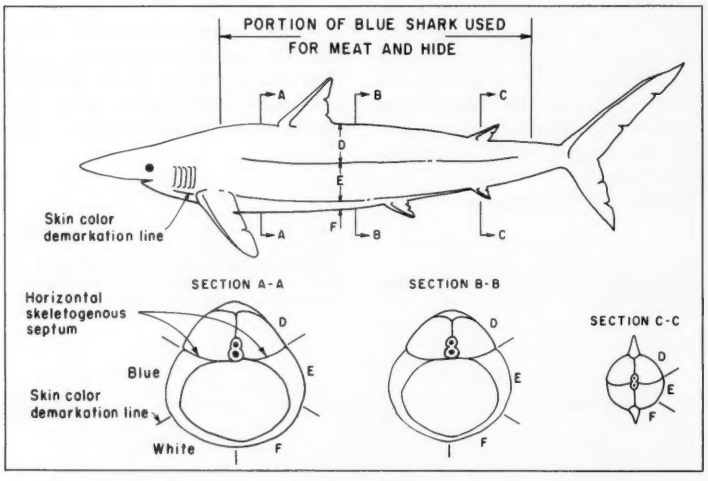


Figure 3.—Sample positions used in determining physical properties of blue shark skin and flesh.

is shown in Figure 2. Other requirements include that hides be at least 1.2 m (40 inches) long and free from sour spots (decomposition), butcher cuts (knife cuts made while skinning), fighting scars, and burnt spots (prolonged exposure to sun before processing). To insure top quality, the hide should be removed as quickly as possible. Hides cannot be frozen or exposed to fresh water without causing wrinkles. They must be fleshed (excess meat removed), salted or pickled for preservation, and packed for shipment.

To provide high quality blue shark products and be compatible with existing fishing techniques, a shark skinning machine would have to be mounted on the fishing vessel. The shark could then be processed immediately. The shark would have to be restrained and killed prior to processing because they are capable of violent movements for up to 40 minutes after landing.

The primary objective of this paper was to determine physical properties of the blue shark important in the design and development of a skinning machine. We further suggest a prototype skinning machine for this species.

Experimental Procedures

Sample Collection and Preparation

Three frozen blue sharks were donated by the commercial fishing vessel *JJ* for our tests. Head, fins, viscera, and tails had been removed prior to shipment. Overall length of the sharks ranged from 1.2 to 1.8 m (4 to 6 feet).

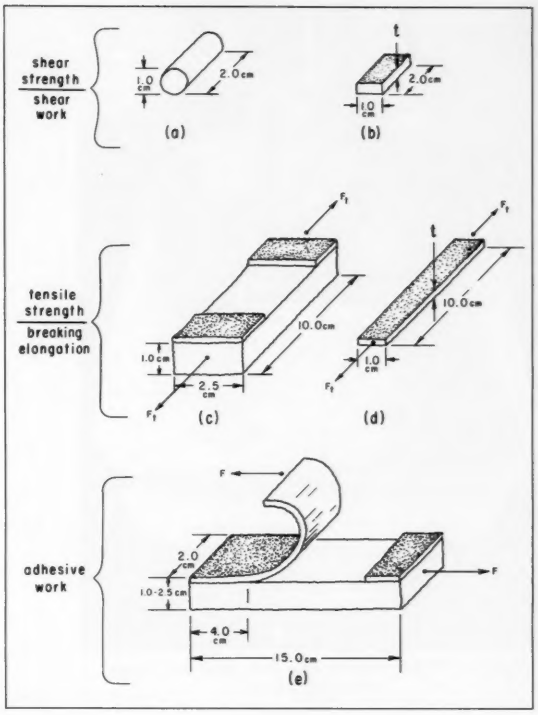
Shark carcasses were thawed at room temperature and samples of skin or flesh were cut at or near (up to 15 cm anterior and posterior) cross sections A, B, and C shown in Figure 3. These sample sections were further differentiated into parts D, E, and F. Part D denotes skin and flesh samples on the dorsal side of the horizontal skeletogenous septum. Position E samples were taken from the ventral side of the horizontal skeletogenous septum above the skin color demarcation line. Position F samples consist of the white skin of the ventral surface and the flesh it covers. Samples were taken from either side of the horizontal skeletogenous septum because of the difficulty it caused in preparing samples.

Each shark was split from head to tail with the shark's right side used for longitudinal skinning and flesh experiments (Fig. 3). The shark's left side was used for radial or dorsoventral experiments. Samples of flesh and skin were cut (Fig. 4a, b) so that the direction of movement of plane of the blade of the Warner-Bratzler-type shear press was parallel to the longitudinal axis or radial to the longitudinal axis as it applied a shear force (Fig. 5). The tensile forces, F_t, applied

by the Instron Universal Testing Machine (Fig. 6) to the flesh and skin samples (Fig. 4c, d) were also applied parallel to the longitudinal axis or from dorsal to ventral. The samples used to determine the adhesive work (force required × distance pulled) required to separate the skin from the flesh (Fig. 4e) were cut so that the skin could be peeled both from head to tail (longitudinally) or from dorsal to ventral.

Two samples of each of the five noted in Figure 4 were taken from each section and position on the three shark carcasses, with the exception of the flesh tensile tests. Because of the thin cross section of the shark flesh and the adherence of the pleuroperitoneal cavity membrane at F (Fig. 3) and the "grain" of the meat at position D (Fig. 3), flesh tensile samples were difficult to prepare.

Figure 4.—Sectioning of blue shark samples: (a) and (c) flesh; (b) and (d) skin; (e) peel test of skin from flesh.



Apparatus and Measurements

Tests to determine tensile strength and breaking elongation (ultimate elongation) of blue shark flesh and skin, and the effort required to separate the skin from the flesh (adhesion work) were performed on an Instron Universal Testing Instrument (Model TM-M, Instron Engineering Corp., Canton, Mass.). The instrument was operated in a tensile mode with a crosshead velocity of 50 cm/minute, with a chart speed of 100 cm/minute, a 50 kg tension load cell, and jaw-type fixtures.

A Warner-Bratzler-type shear press, built by the Food Science Department, University of California Davis, was used to determine the shear strength and shear work of blue shark flesh and skin. The shear blade was mounted in the crosshead of the Instron Testing Instrument and the anvil, against which the blade shears the shark samples, rests on the Instron's 50 kg compression load cell (Fig. 5). Crosshead speed remained 50 cm/minute and chart speed 100 cm/minute. The equation used to calculate shear strength, S, for this type of double shear is described by Mohsenin (1970):

$$S=\frac{F_s}{2A},$$

where F_s is the maximum force recorded by the Instron (Fig. 7b) and A is the cross-sectional area of the shark sample. Shear work is represented by the area under the force-distance curves generated by the Instron (Fig. 7b).

Tensile strength and breaking elongation of flesh and skin were measured with the samples of skin and flesh held in the jaw fixtures (Fig. 6). The crosshead moved upward until the sample ruptured. The maximum force was recorded for calculation of tensile strength, T, and the distance the crosshead traveled for calculation of breaking elongation. A schematic representation of the Instron output is shown in Figure 7a.

Tensile strength is defined by the following equation:

$$T=\frac{F_t}{A},$$

where A is the original cross-sectional area of the skin or flesh sample. The percent elongation after fracture of the skin and flesh samples is given by the equation:

$$\frac{l_f-l_i}{l_i}\times 100,$$

where l_i is the initial length of the sample and l_f is the final length as the sample ruptures.

Adhesive work was determined by performing a modified T-peel test, ASTM D1876-61T (Cagle, 1968). The shark peel test specimens are seen in Figure 4e and in the jaws of the Instron in Figure 8. With the Instron in a tensile mode the crosshead moves upward peeling the skin from the flesh. Figure 7c gives a schematic representation of the Instron output for the adhesive work tests. Adhesive work is represented by the area under the force-distance curve. The calculated value for adhesive work was then divided by the area of skin removed (Figure 4e).

Figure 5.—Warner-Bratzler-type shear press and sample of blue shark flesh.

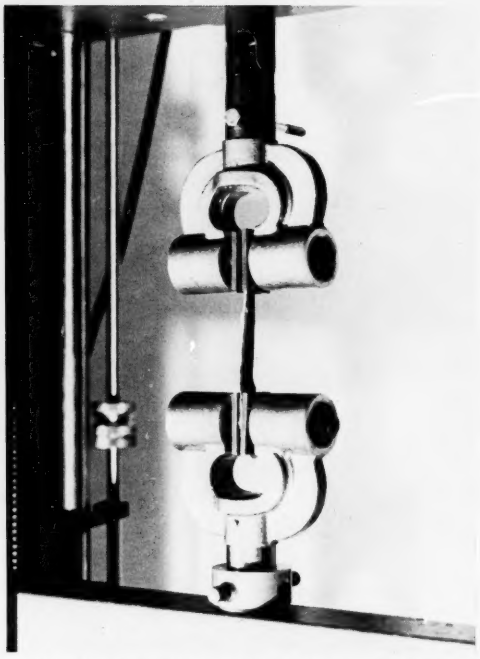


Figure 6.—Tensile test of blue shark skin mounted in jaws of Instron Universal Testing Machine.

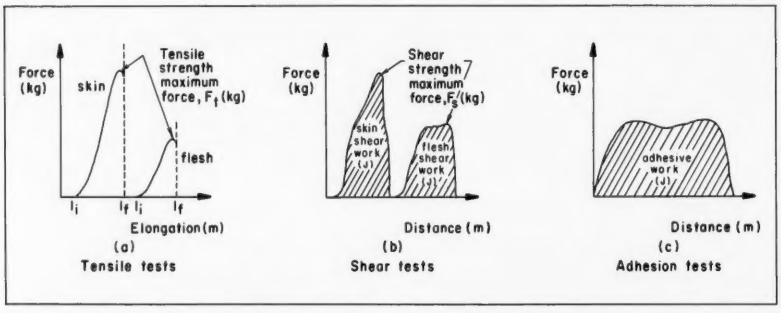


Figure 7.—Schematic force-distance curves: (a) tensile, (b) shear, (c) adhesion tests.

Results and Discussion

Tensile Strength and Breaking Elongation

The range of recorded values for tensile strength of blue shark skin (Fig. 9) was found to be 2 orders of magnitude greater than the tensile strength of the flesh at sample position b (Fig. 10). The tensile strength of the skin ranged from 3 to 13 MPa. No significant differences appear for tensile strength of skin with respect to sections A, B, or C or the direction of applied force. The tensile strength of shark skin at sample position F does tend to be higher than those for positions D and E. This is despite the fact that the white skin at position F

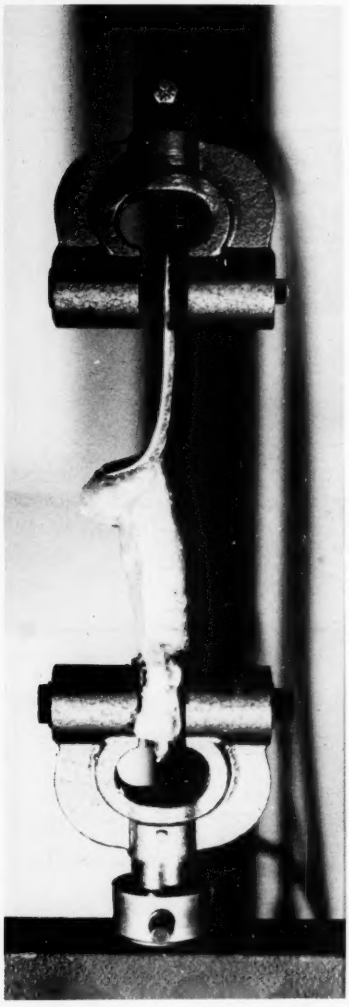


Figure 8.—Blue shark sample ready for adhesion testing in Instron Universal Testing Machine.

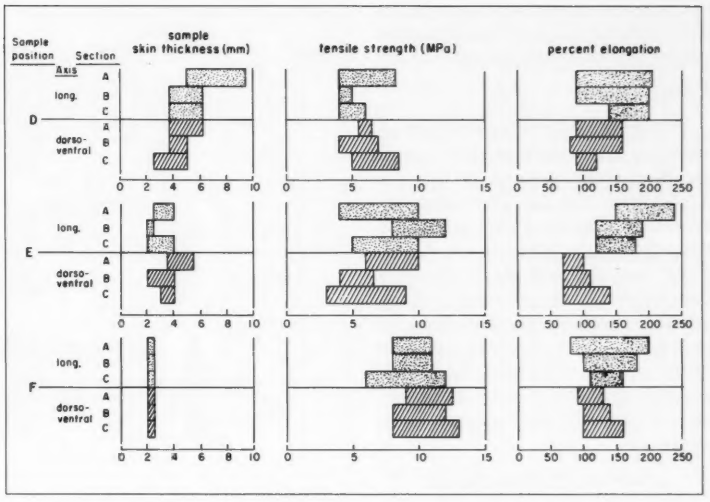


Figure 9.—Tensile strength and breaking elongation of thawed blue shark skin (Instron Universal Testing Machine).

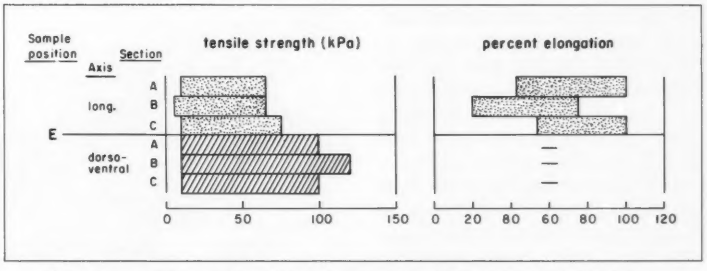


Figure 10.—Tensile strength and breaking elongation of thawed blue shark flesh (Instron Universal Testing Machine).

(ventral surface) is quite thin and supple.

Breaking elongation of blue shark skin varied from 70 to 240 percent (Fig. 9). The majority of skin samples tested stretched over 100 percent before breaking. Breaking elongation of blue shark flesh at position E, along the longitudinal axis, ranged from 20 to 100 percent (Fig. 10).

Shear Strength and Shear Work

Figures 11 and 12 show the range of shear strength and shear work recorded for skin and flesh, respectively. Using the Warner-Bratzler-type shear press, the shear strength of the blue shark skin, 1.5-12.5 MPa, was found to be at least 20 times greater than that of the flesh, 30-600 kPa. The shear strength of the dorsally located skin, position D, tended to be less than that for the ventral surface, position F. The range of values recorded for shear work (area under force-distance curve), at position D, the dorsal area, are 2-6 J. Because of the greater thickness of the dorsal skin, the shear work has the tendency to be higher than for position E, 1-4 J, and the ventral surface, position F, 0.5-4.5 J. Little variance was found in shear strength or shear work of skin with respect to section or direction of applied force.

The range of shear work recorded for blue shark skin, 0.5-6.0 J, was 3-50 times greater than that for flesh (0.01-2.2 J).

Adhesive Work

The range of values recorded for adhesive work, pulling skin from flesh, in the blue shark samples tested was 0.2-3.2 kJ/m^2 (Fig. 13). The highest values recorded occurred when peeling the skin covering the tail of the shark, section C, parallel with the longitudinal axis. In general, the adhesive work required to peel the shark from dorsal to ventral was lower. Stretching of skin during peeling was negligible. These two facts could be of some advantage when skinning the shark in the manner proposed.

A Skinning Machine Design

As noted, the effort required to skin blue shark from dorsal to ventral surface was lower than that for the longitudinal direction. It was also observed by the authors that the amount of meat remaining on the skin after the dorsal to ventral peel tests was less than that for the longitudinal tests. The amount of meat remaining after the peel tests was also lower than that left when shark skin is pared from the flesh manually with a knife. If the skins are removed by pulling, from dorsal to ventral surface, it would be easier to flesh the hide. These observations, plus the requirement by processors that no butcher cuts be made in the hide, make it advantageous to peel the skin from the shark rather than cut it away from the flesh.

The authors envision a machine, on board ship (Fig. 14), which would restrain the shark initially in a retractable cage as the shark is landed. The shark, restrained by the bars of this cage which have a wide enough spacing to allow the caudal and dorsal fins to protrude (Fig. 15A), is conveyed to a skinning and gutting station on the ship. The cage and shark are then rotated on their longitudinal axis so that it can be restrained with a row of spikes or augers mounted on a rigid beam (Fig. 15B). These would penetrate the dorsal surface of the shark, after removal of the dorsal fin, and into the spine, skull, and brain. The spine and skull of blue shark is easily penetrated. This would effectively kill the shark and reduce the nervous activity and movements of the shark[4] which would otherwise interfere with the skinning process and hide quality. Although the hide has been ruptured on the dorsal side, the desired form of the hide is still intact. The caudal and pectoral fins could then be removed and saved, and

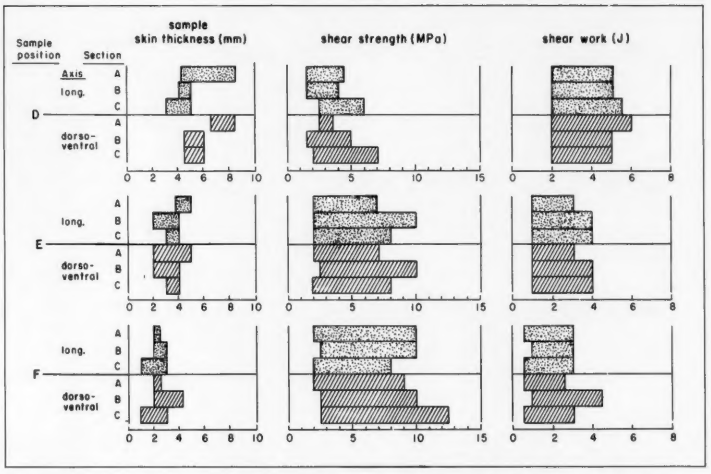


Figure 11.—Shear strength and shear work of thawed blue shark skin (Warner-Bratzler-type shear press).

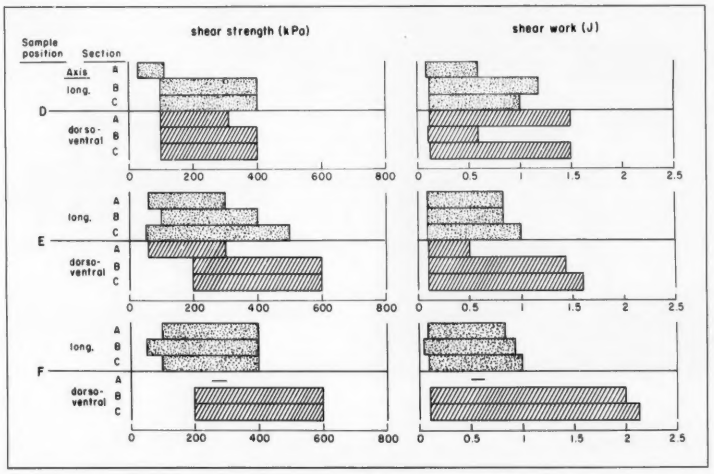


Figure 12.—Shear strength and shear work of thawed blue shark flesh (Warner-Bratzler-type shear press).

[4]Nelson, D. R., California State University, Long Beach, Calif. Pers. commun., 1980.

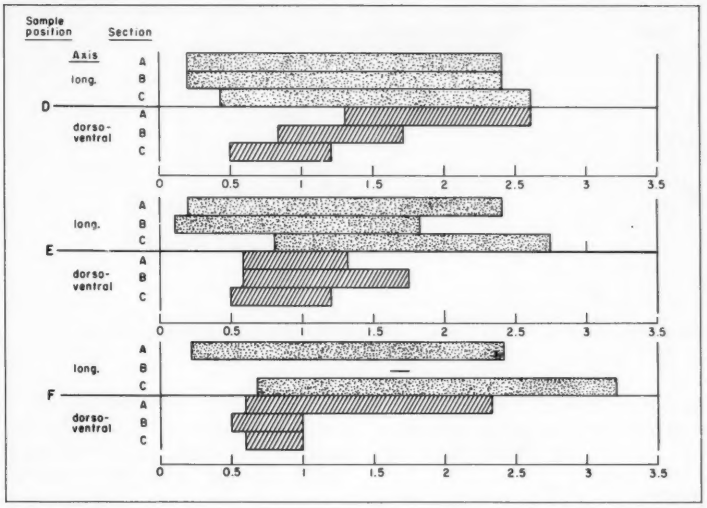


Figure 13.—Adhesive work required to skin thawed blue shark (Instron Universal Testing Machine) (kJ/m^2).

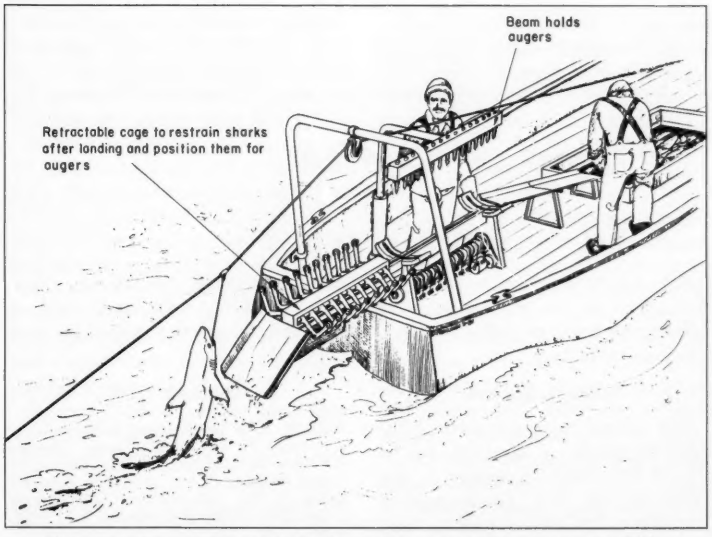


Figure 14.—Proposed blue shark skinning machine onboard ship using longline fishing technique.

the tail can then be severed, thus bleeding the shark.

A hand operated knife (Fig. 16) used to open deer carcasses for gutting, by cutting from the inside, was successful in making the full-length dorsal cut. A tool of this type could mechanically follow the row of restraining spikes proposed above along the dorsal ridge of the shark to start the skinning process (Fig. 15C). This hide cut (Fig. 2) would be made on the left and right hand sides of the dorsal ridge as close to its apex as possible. Because of the toughness of the hide, replaceable or disposable blades would be required.

Skin grippers of the type commercially used to manually remove strips of skin from dogfish sharks (Atlas, 1978) could be modified to grip the blue shark skin at the incisions along the dorsal ridge described above (Fig. 15C). Cables attached to these grippers could then mechanically pull the skin away from the flesh (Fig. 15D), around to the ventral side, and off the carcass (Fig. 15E). The hide could then be fleshed and trimmed to the form of Figure 2. The carcass would then be gutted and put in cold storage.

However, the horizontal skeletogenous septum (Fig. 3) may have to be severed from the inside of the skin. The adhesive work required at its point of attachment to the skin was found to be 2-3 times that at other points on the body. The shear work required to sever it is approximately equal to that for the skin on the dorsal surface. The knife-type tool (Fig. 16) could be reinserted to make the cut along the horizontal skeletogenous septum. Such a knife would minimize the risk of making butcher cuts in the hide.

Summary and Conclusions

The tensile strength of blue shark skin ranges from 3 to 13 MPa and is 2 orders of magnitude greater than that of the flesh. Shear strength of the skin was approximately equal to the tensile strength of the skin and ranged from 1.5 to 12.5 MPa. Shear strength of the skin was 20 times greater than that of the flesh.

Shear work for blue shark skin ranged from 0.5 to 6.0 J and was 3-50 times greater than that for the flesh. The adhesive work required to peel the skin from the flesh of blue shark ranged from 0.1 to 3.2 kJ/m^2. Less work was required to peel the shark from dorsal to ventral side.

In conclusion, a machine could be

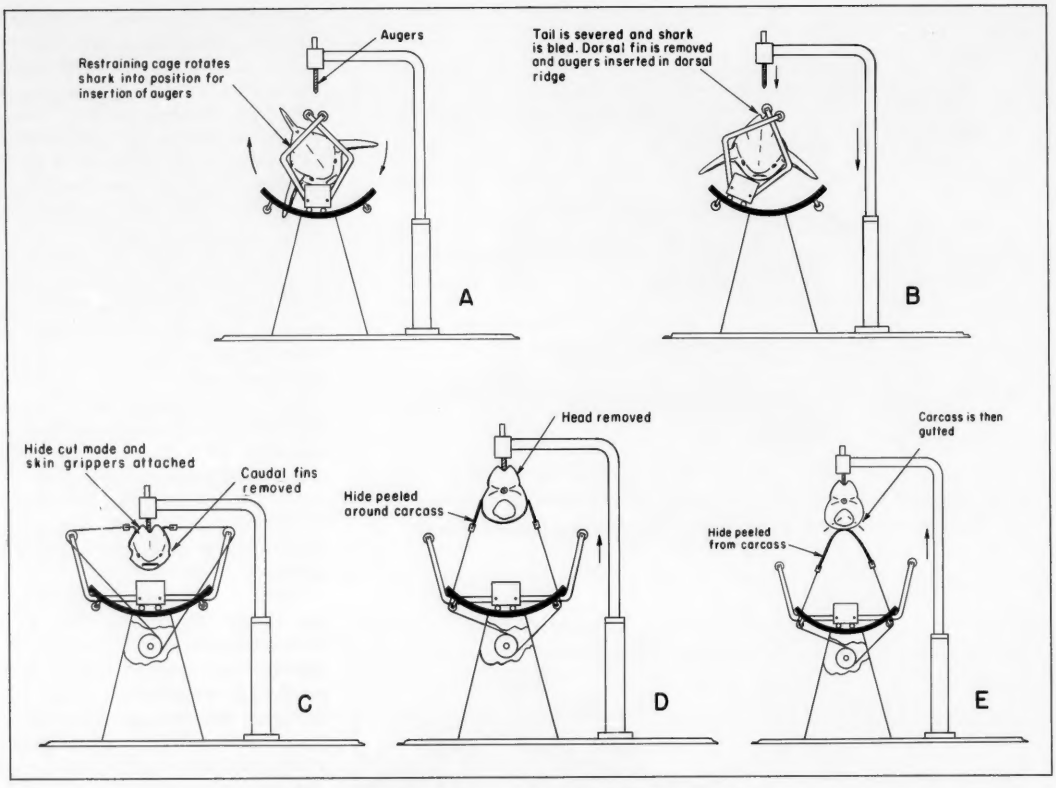


Figure 15.—End view of proposed skinning machine for blue shark.

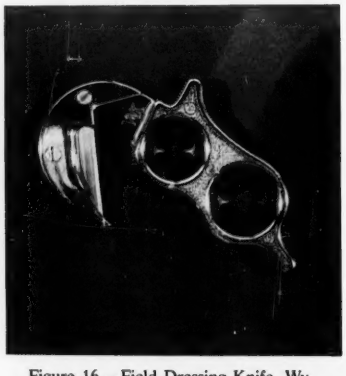


Figure 16.—Field Dressing Knife, Wyoming Knife Corp., Casper, Wyo.

built to pull the skin from the blue shark in one piece, as a commercial means of skinning the shark, by pulling from dorsal to ventral surface.

Acknowledgments

This investigation was part of the study "Feasibility of Mechanical Skinning of Blue Shark" supported by Sea Grant, NOAA, U.S. Department of Commerce. The authors wish to thank the captain, John Christen, and crew member, Jane Meyer, of the fishing vessel *JJ* for their generous hospitality and assistance during our stay on their vessel and for providing us with sharks for this study. Contributions of James L. Bumgarner, University of California, Davis, and Dwight Morejohn, Davis, Calif., in preparing the figures is gratefully appreciated.

Literature Cited

Atlas, M. 1978. Development of processes for skinning the spiny dogfish shark. Master's Thesis, Massachusetts Institute of Technology, Cambridge, 50 p.

Brody, J. 1965. Fishery by-products technology. AVI Publishing Company, Inc., Westport, Conn., 232 p.

Cagle, C. 1968. Adhesive bonding. McGraw-Hill Book Company, N.Y., 351 p.

Mohsenin, N. 1970. Physical properties of plant and animal materials. Vol. 1, 734 p. Gordon & Breach Science Publ., N.Y.

NOAA. 1980. Fisheries of the United States, 1979. Curr. Fish. Stat. 8000. U.S. Dep. Commer., Wash., D.C., 131 p.

Foreign Fishing Fleets Fined $6.3 Million

Foreign fishermen have been fined more than $6.3 million during the past 4 years for violating regulations on fishing in the United States' 200-mile fishery conservation zone.

The Commerce Department's National Oceanic and Atmospheric Administration (NOAA) reports 56 ships from 9 foreign nations have been seized and fined for the violations. Most fines were imposed for underlogging the amount of fish on board, fishing without a permit, or failing to return prohibited species to the ocean. All of the penalties were levied under the Magnuson Fishery Conservation and Management Act.

Japan has had the most seizures—19—and has paid almost $3.4 million in fines. The Japanese also have posted an additional $2 million in bond for seven ships that were seized and released. A final settlement on these vessels has not been reached. The largest single fine, $700,000, was levied in 1979 against a Japanese vessel in the Bering Sea which had about 54 tons of fish on board that was not logged as required.

Fifteen Mexican vessels have been seized and assessed more than $90,000. Most were shrimp boats caught fishing without a permit in U.S. waters in the Gulf of Mexico. Seizures and fines levied against other countries were: Taiwan, 6 vessels, $855,000; Russia, 3 vessels, $650,000; South Korea, 3 vessels, $400,000; Spain, 3 vessels, $255,000; Canada, 3 vessels, $5,816; Poland, 2 vessels, $387,000; and Italy, 2 vessels, $300,000.

Twenty-eight vessels were seized in waters off Alaska and 16 in the Gulf of Mexico. Six were taken off the U.S. east coast, four off the west coast, and two in the western Pacific.

Canada and U.S. Sign Treaty on Pacific Coast Albacore Vessels, Ports

The United States and Canada have concluded a Treaty on Pacific Coast Albacore Tuna Vessels and Port Privileges, according to the U.S. Department of State. The Treaty was signed 26 May in Washington, D.C., by Deputy Secretary of State William P. Clark and Canadian Ambassador Peter M. Towe.

This long-term agreement replaces an interim arrangement for the albacore fishery off Canada and the United States that expired 1 June and will provide greater benefits for the tuna fishermen of both countries. The Treaty provides reciprocal port privileges for albacore vessels of the United States and Canada and ensures that fishermen of both countries can fish for albacore off the Pacific coast, pursuant to the Treaty, without risk of seizure.

Under the Treaty, each country will open four of its west coast ports to albacore fishermen of the other country for loading fuel and using other services. The four U.S. ports are Bellingham, Wash.; Astoria, Oreg.; Coos Bay, Oreg.; and Crescent City, Calif. U.S. albacore fishermen will receive privileges in the British Columbia ports of Prince Rupert, Port Hardy, Victoria, and Ucluelet.

LaCovey Is Named NOAA Public Affairs Director

A. Joseph (Jack) LaCovey, a vice president of Burson-Marsteller, has been named director of public affairs for the Commerce Department's National Oceanic and Atmospheric Administration (NOAA). LaCovey was a presidential staff assistant in 1976-77 and an assistant to the director of the National Park Service in 1974-75. He directed the Service's $5 million bicentennial commemoration.

From 1969 to 1974, LaCovey was director of special projects for the General Services Administration (GSA) and an award winning news correspondent and documentary producer for Washington's WMAL AM-TV from 1961 to 1969.

LaCovey's numerous broadcasting awards included a 1969 Emmy from the Washington Chapter of the National Academy of Television Arts and Sciences for the television documentary, "Courts on Trial," and an Edward R. Murrow International Documentary Award from the Radio-Television News Directors Association. He received a bachelor's degree in radio and TV broadcasting from Ithaca (N.Y.) College in 1961. LaCovey and his wife, the former Carol Chase of Crete, Ill., and their four children, reside in McLean, Va.

New NOAA Satellite Launched in June

A new and improved environmental monitoring satellite was launched on 22 June, giving the fishing and marine transportation industries, weather forecasters, and others access to improved sea surface temperature information. The Commerce Department's National Oceanic and Atmospheric Administration (NOAA) and the National Aeronautics and Space Administration (NASA) said the satellite, NOAA-7, carries the most versatile scanning radiometer ever sent aloft in such a spacecraft. It gathers visual and infrared imagery and measurements in five spectral channels.

The data should permit more accurate evaluation of land, ice, and water surface temperatures, as well as clouds. Two earlier TIROS-N satellites carried four-channel radiometers. One is still operational. The satellite was launched from Vandenberg Air Force Base, California.

The sea surface temperature data will be valuable to west coast and Gulf of Alaska fishermen and shipping interests along the east coast and in the Gulf of Mexico. Fishermen use charts of sea surface temperatures to pinpoint productive fishing grounds. Many credit the charts with helping improve catches and cut fuel costs. Shippers use similar charts for the Gulf Loop current and Gulf Stream, saving time and money.

Keeping Quality of Fresh and Frozen Widow Rockfish

Landings of the widow rockfish, *Sebastes entomelas,* a species little known until the last few years, have contributed significantly to the increase in total rockfish landings in the Pacific Northwest from about 66 million pounds in 1979 to 80 million pounds (preliminary data) in 1980. Widow rockfish are harvested by Oregon trawlers using midwater trawls and fishing just off the coast at night. The fresh fish are landed later the same day, filleted, and rushed to fresh fish markets along the coast. Experience with the species showed that the fresh refrigerated fillets are highly perishable and should be marketed within 6 or 7 days. Discoloration of the skin and flesh and development of off-odors are the indicators of unacceptability in this species.

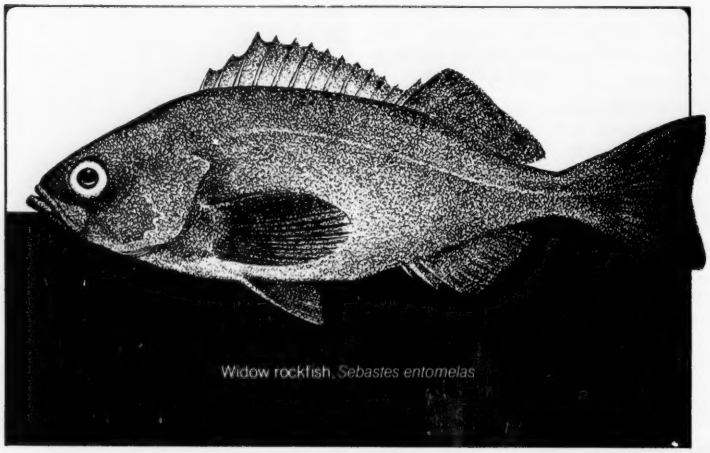
The increased landings of widow rockfish and its popularity as a moderately priced fillet fish soon resulted in freezing and storage of the packaged fillets as the processors sought to stabilize the fishery. Our laboratory obtained frozen widow rockfish fillets from a commercial processor in northern California to determine the characteristics and storage life of the frozen fish. Individual species of *Sebastes* vary in cold storage characteristics; therefore each species must be tested separately.

The Utilization Research Division of the NMFS Northwest and Alaska Fisheries Center recently examined the widow rockfish fillets after 4 months of storage at 0° and −20°F. Development of rancidity in the exposed flesh areas and the dark meat of fillets stored at 0°F were rated moderate to severe. Considerable variation was apparent from various fillet portions; however, the conclusion is that the fillets stored at 0°F were unacceptable after 4 months. The fillets stored at −20°F were superior to those stored at 0°F and deep-fat-fried fillets stored at −20°F were rated good. The problem of variability depending on exposure was still noted, however, in the −20°F samples. Texture differences were measured by thaw, cook, and expressed drip and showed no significant differences in relation to the storage temperature.

The rapid development of severe rancidity in some widow rockfish fillets stored at 0°F for only 4 months indicates a serious problem in keeping quality. It appears from this initial study that pretreatment with additives to inhibit oxidative changes, good packaging, and storage at the lower temperature are essential for extending the keeping quality of frozen widow rockfish fillets. Further work on freezing and holding widow rockfish is planned in conjunction with resource assessment studies of rockfish off Washington and Oregon.

The research on freezing and storage of this series of samples is being conducted by Jim W. Conrad, NOAA Corps, on assignment to the Utilization Research Division, NWAFC.

John Dassow



Widow rockfish, *Sebastes entomelas*

Hydrolab Unit Eyes Coral Reefs, Fisheries

Scuba-diving scientists operating from NOAA's undersea laboratory Hydrolab have been conducting four experiments this summer aimed at better management of coral reefs and their fishery resources.

Located at a depth of 50 feet near the mouth of the Salt River off St. Croix, U.S.V.I., Hydrolab holds four scientists for up to 2 weeks at a time, permitting them to swim out into the water to conduct research. The projects, which started 4 June, make use both of the natural coral reef near Hydrolab and the nearby artificial reef constructed for comparison studies, NOAA officials said.

John Ogden of Fairleigh Dickinson University's West Indies laboratory

headed a team to implant ultrasonic tags under the skin of 40- to 50-pound parrotfish—a vegetarian species—to follow their meanderings as they forage the area for seagrass. Parrotfish are the chief catch in Virgin Island fish pots, so mapping their habits will lead to better management of resources in the nearly fished-out waters, Ogden said. His team used Hydrolab 4-16 June and included scientists from the Bernice P. Bishop Museum of Honolulu, Hawaii, and the Government of the U.S. Virgin Islands.

Les Kaufman and John Ebersole of the University of Massachusetts studied whether colonization of a reef is chaotic and haphazard, as is commonly believed, or organized and predictable, as Kaufman surmises. They compared fish inhabiting natural reefs with those in an artificial reef, and studied the body design and eating habits of reef fish to correlate them with the fish's range of activity. The results will be used to manage coral reefs for recreational diving. Their research was conducted from 23 June to 5 July.

Kaufman's project was inspired by research undertaken by M. L. Reaka of the University of Maryland. From 12 to 24 July, she made her third study of factors affecting the way a reef is colonized. Invertebrates such as crab and shrimp, she believes, determine how many fish settle on a reef. They are the chief food source of carnivorous species. She baits artificial reefs with invertebrates that attract smaller fish and in turn lure larger, commercially valuable species. One purpose of her research is to establish a reef construction model that will effectively attract the larger fish.

William McFarland of Cornell University led a team study from 1 August through 13 August studying the early life stages of coral reef fish and aggression in young and adult fish. They examined vision in the open water phase of larval fish to determine their relative sensitivity to blue light, and studied otoliths to calculate how old the fish are when they settle on the reef. Edward B. Brothers, who accompanied McFarland, said that what they learn about the larval stage—the most critical period in a fish's life—can be used to increase the survival rate of commercially important species.

NOAA's Hydrolab at present is the only undersea habitat operated by the United States. It was constructed in 1971 and bought by Perry Oceanographics, Inc.[1], for studies off Florida and the Bahamas. NOAA purchased and refurbished it in 1978 and moved it to the St. Croix location.

Fairleigh Dickinson's West Indies laboratory operates Hydrolab for NOAA. It is the first of a planned network of regional university-based undersea research facilities sponsored by NOAA. The second, the Hawaii Undersea Research Laboratory (HURL), was dedicated early in May.

New Hawaiian Undersea Laboratory Is Dedicated

Sponsored by NOAA, the Hawaii Undersea Research Laboratory (HURL) was dedicated in Waimanalo, Hawaii, in early May 1981. The laboratory is the second in a planned NOAA network of university-based undersea research facilities.

HURL consists of the two-person submersible *Makali'i* and a launch-recovery-transport vehicle. Under the direction of John Craven, Dean of Marine Programs at the University of Hawaii, HURL will concentrate its research on fisheries, pollution, sea-floor properties and processes, and ocean technology and services.

Scientists from Stanford University and the University of Hawaii will use the *Makali'i* to study and collect deepwater sponges and gorgonians (sea fans) for possible use as marine pharmaceuticals. One series of dives has been made on the Penguin Rocks off the island of Molokai.

A second research project, begun in July, involved lengthy scientific observations at Eniwetok Atoll, formerly a nuclear weapons test site, some 2,400 miles west of Hawaii. While the shallow waters of the atoll have been more extensively studied than any other atoll in the world, little is known about the waters of the lagoon—about 90 percent—that are below scuba depth. Nor is much known about the deep ocean waters surrounding the 360-square-mile atoll and lagoon.

Scientists wish to understand more fully the deeper ocean environment and ecology of the area to better advise the original islanders who have resettled there. Scientists from the Mid-Pacific Research Laboratory on Eniwetok, and other institutions, will use the HURL facilities to study the geology, biology, and radiochemistry of the tropical reef.

[1]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

The research submersible *Makali'i*.

The Tuna Fisheries of Cape Verde and Senegal

Cape Verde

The tuna fishery of Cape Verde is yet small but plays a major role in the country's fishing industry industry which caught only about 8,300 metric tons (t) of fish in 1978, (6,300 t were caught by artisanal fishermen and 2,000 t by commercial fishermen). The two most important fisheries are shellfish (shrimp and lobster) and tuna, but precise catch data is unavailable.

Even though the catch is small, the fishing industry is a vital sector of the Cape Verde economy. Fish is a substantial proportion of the protein consumed in Cape Verde. Fishery products are also the most important single export commodity, accounting for about 30 percent of the country's total exports in 1978. When Cape Verde's exports of used cars and scrap iron are excluded, fishery products account for over 70 percent of the country's domestically produced exports.

Tuna is the single most important species caught by Cape Verde fishermen. It makes up most of the commercial catch and is also important to artisanal fishermen. Most of the tuna caught since 1976 has been skipjack tuna.

Fleet

Cape Verde's commercial tuna fleet consists entirely of pole-and-line vessels. Most are 15 m vessels used for fishing within 5 miles of the islands. The fishermen return to port daily and do not carry ice. The only large vessels, three 34 m vessels with carrying capacities of 200 t, are owned and operated by the state-owned company, INTERPESCA[1], off Cape Verde from June to December.

Beginning in 1979, INTERPESCA deployed its vessels off Angola during the remainder of the year. The NMFS Division of Foreign Fisheries Analysis believes the catch off Angola is mostly landed and processed in Angolan ports. The INTERPESCA vessels were originally purse seiners, but have been converted to pole and liners. The Government has been organizing a new company, PESCANAVE (footnote 1), which plans to obtain small multi-purpose vessels with carrying capacities of about 15 t to fish for both tuna and demersal species.

Processing

There are five canneries and three cold stores in Cape Verde. The canneries process tuna received from both artisanal and commercial fishermen, and have capacities ranging from 2 to 5 t per day[2]. Cape Verde has three major cold stores, all of which are believed to be located at the port of Mindelo. FRICAP (footnote 1) operates a 3,000 t cold store which in the future will be used for the domestic market. INTERMAR (footnote 1) will operate a new 6,000 t cold store which will be used primarily for exports. The INTERMAR cold store is being financed by a $3.2 million grant from the Dutch Government and the contract has been awarded to a Dutch refrigeration company, Grenco. The third cold store is privately owned and has a capacity of 600 t.

Exports

Almost all of Cape Verde's tuna catch is exported. The canneries export primarily to Europe. FRICAP and the smaller cold storage company export to Portugal and Italy for canning in those countries. Unconfirmed reports indicate that INTERBASE has negotiated a purchase agreement with a U.S. company, so exports in the future may be directed to the United States. Tuna exports totaled $360,000 in 1978, nearly 70 percent of total fishery exports of $525,000 (Table 1). Export earnings declined in 1978, primarily because of poor tuna catches. Unconfirmed reports indicate that catches in 1979 and early 1980 were substantially above 1978 levels so exports probably increased during those periods.

Development

The Government of Cape Verde took two major steps in the late 1970's which indicate the increased emphasis which it is placing on fisheries. The first step was to declare a 200-mile Exclusive Eco-

Note: Unless otherwise credited, material in this section is from either the Foreign Fishery Information Releases (FFIR) compiled by Sunee C. Sonu, Foreign Reporting Branch, Fishery Development Division, Southwest Region, National Marine Fisheries Service, NOAA, Terminal Island, CA 90731, or the International Fishery Releases (IFR) or Language Services Biweekly (LSB) reports produced by the Office of International Fisheries Affairs, National Marine Fisheries Service, NOAA, Washington, DC 20235.

[1]A Government-owned holding company, INTERBASE, manages 6 subsidiary companies in the fisheries sector, including PESCANAVE, INTERPESCA, FRICAP, and INTERMAR.

[2]It is not known whether this quantity is the live weight of the fish or the canned and frozen tuna.

Table 1.—Cape Verde fishery export values (US$), 1976-June 1979.

Commodity	Export values (× 1,000)			
	1976	1977	1978	1979[1]
Tuna				
Canned	$156.2	$384.6	$198.4	NA[2]
Frozen[3]	196.3	127.3	162.2	$88.5
Total	352.5	511.9	360.6	NA
Other finfish	7.7	9.3	–	NA
Shellfish	242.0	131.9	162.7	79.0
Fish meal	28.4	16.6	2.3	5.2
Total	$630.6	$669.7	$525.6	NA

[1]January to June.
[2]NA=Not available.
[3]Includes an unknown (but probably small) quantity of species other than tuna.
Source: NMFS Division of Foreign Fishery Analysis estimates.

nomic Zone (EEZ) in February 1978. Since that time, the Government claims to have been conservative in allocating fishing rights within the EEZ. It is not known which, if any, countries have applied for Cape Verde licenses. The second step was to join the International Commission for the Conservation of Atlantic Tunas (ICCAT) in October 1979, making Cape Verde the 19th member of the Commission.

The Government of Cape Verde plans to expand its tuna fishery. Foreign nations desiring to fish in the Cape Verde 200-mile EEZ will be required to assist Cape Verde develop its fishing industry, and land part of their catch in Mindelo for transshipment through Cape Verde. The country has negotiated agreements with FAO, the Arab Bank for the Economic Development of Africa, and the Governments of Abu Dhabi and Saudi Arabia to finance the purchase of tuna vessels. Cape Verde hopes that these vessels will enable the country to catch about 40,000 t of tuna annually. Although achieving that goal and expanding port facilities at Mindelo into a major tuna transshipment center could take several years. The Government's decision to promote the industry's development, however, may eventually make Cape Verde's tuna fishery one of the most important in Africa. (Source: IFR-80/180.)

Senegal

The Republic of Senegal has one of the largest and most developed fishing industries in West Africa. Senegal's 700 km coastline borders on waters that, because of seasonal coastal upwelling, contain some of West Africa's richest fishery resources. Fisheries represent one of the most important sectors in Senegal's economy, accounting for about 7 percent of the gross domestic product. The fishing industry supplies food for domestic consumption and is a significant source of foreign exchange. In recent years government policy has favored commercial fishing over artisanal fishing, although both have been accorded high priority in Senegal's development plans. Senegal's highly developed tuna fishery, one of West Africa's largest, is dominated by the commercial sector.

Vessels, Ports, and Season

Senegal was one of the first West African countries to acquire commercial tuna vessels. Some of the earliest vessels were obtained from the Soviet Union, which delivered 10 vessels in all by 1975. The Senegalese fishermen, however, encountered significant maintenance problems with the Soviet vessels and claim they were unsuitable for local conditions. Senegal now relies primarily on West European and U.S. shipyards for its tuna vessels.

The Senegalese commercial tuna fleet in 1979 consisted of 34 vessels[3], 31 pole-and-line and 3 purse seiners. French interests own 30 of the pole-and-line vessels; the remaining vessels are Senegalese-owned. The number of vessels in Senegal's tuna fleet has declined since 1974, when there were 42, 26 of them French-owned.

The three Senegalese purse seiners were built in the United States during 1975. The *Jilor, Jofondor,* and *Niomre* have carrying capacities of 800 t each, a top speed of 15 knots, and an operating range of 7,000 n.mi. Reportedly, all three vessels experienced considerable maintenance difficulties in 1979 and it appears that one was inoperable for most of the year.

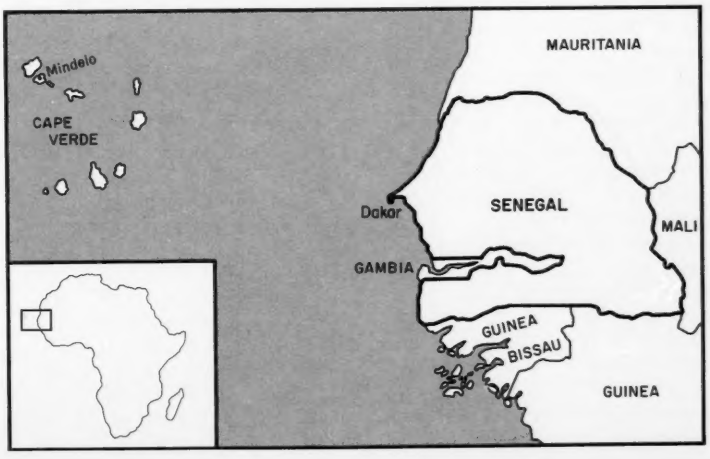
Senegal's tuna fleet is based in the capital city of Dakar (population 800,000), long a commercial center in West Africa. Dakar offers excellent cold storage and freezing facilities and maintains extensive communication and air links with other areas of the world. A new fishing pier was completed in October 1980 after 3 years of construction. Reportedly one of the most modern complexes of its kind in West Africa, the pier is equipped with facilities to provide water, oil, electricity, and telephone service to fishermen.

Senegalese fishermen report their largest catches during the summer months from May to October, although an occasional large catch in other months is not unusual. In 1978, 80 percent of Senegal's total tuna catch occurred during the summer season; in 1979, 93 percent of the tuna was caught during the same period. Senegal's tuna season corresponds to the cycles of upwelling which begin in May when the prevailing northeasterly tradewinds shift, and continues until November.

Species

Skipjack and yellowfin tuna are the most important species caught by Senegalese fishermen. Yearly variations in

[3]It is not known whether these are French-flag vessels based in Senegal or Senegalese-flag vessels owned by the French.



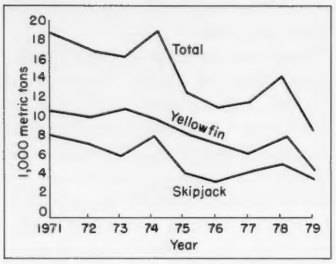


Figure 1.—Fluctuations in the Senegalese tuna catch, 1971-79.

Table 2.—Senegal's tuna catch, by species, 1971-79.

Year	Catch (t)			
	Yellowfin	Skipjack	Bigeye	Total
1971	10,300	8,100		18,400
1972	9,900	7,300		17,200
1973	10,400	6,300		16,700
1974	9,937	9,365	64	19,366
1975	8,325	4,312	19	12,656
1976	7,409	3,504	73	10,956
1977	6,847	5,055		11,902
1978	8,563	6,469		15,032
1979	4,785	4,231	99	9,115

Source: Ministry of State for Marine Fisheries, Directorate of Oceanography and Marine Fisheries, "Resultats Generaux de la Peche Maritime Senegalaise," 1979, and FAO "Yearbook of Fishery Statistics," various years.

Table 3.—Senegal tuna cannery production, 1978-79.

Company	Capacity	Production (t)			
		1978		1979	
		Amt.	%	Amt.	%
SAPAL	10,000	7,776	40	6,976	51
SNCDS	10,000	9,346	48	5,372	39
SAIB	3,500	1,839	10	1,438	10
Other		423	2		
Total	23,500	19,384		13,787	

Source: Ministry of State for Marine Fisheries, Directorate of Oceanography and Marine Fisheries, "Resultats Generaux de la Peche Maritimes Senegalaise, 1979."

the skipjack catch have paralleled changes in the tuna catch as a whole (Fig. 1). Skipjack tuna comprised 43 percent of the catch in 1978 and 48 percent in 1979. The yellowfin catch, however, has been more stable, particularly from 1974 through 1978. Yellowfin tuna composed 57 percent of the catch in 1978 and 52 percent in 1979. A third species found in Senegalese waters, bigeye tuna, is of negligible significance.

Catch and Landings

Senegal's tuna catch has fluctuated greatly over the past 9 years and particularly since 1974. From a record total of almost 19,400 t in 1974 the catch declined by 33 percent in 1975 and a further 11 percent in 1976 (Table 2). These declines were at least partially due to labor and managerial problems experienced by the state fishing company, SOSAP (Societe Senegalaise d'Armament de la Peche). SOSAP also encountered difficulties with its Soviet-built purse seiners, many of which were idled for long periods of time. In 1977 and 1978 and tuna catch increased, but in 1979 it fell again, by almost 40 percent from 1978 levels, and was the smallest catch since 1966. This decline is at least partially attributable to hydrological conditions which affected tuna migratory patterns during most of the year in certain areas along the West African coast.

Almost all of the Senegalese tuna catch is landed at Dakar. In addition, foreign vessels fishing off Senegal are required to land a portion of their catch in Dakar also. Spanish vessels, as stipulated by a bilateral agreement between Spain and Senegal, landed 2,500 t of tuna in Dakar in 1978 and 2,100 t in 1979. Vessels of the French company SOVETCO (Societe de Vente de Thon Congele), which manages French, Ivorian, and Moroccan tuna vessels off West Africa, also land part of their catch in Dakar. SOVETCO vessels landed 1,850 t in Dakar in 1978 and 2,600 t in 1979. In addition to the landings, foreign fishermen also transship tuna through Dakar, the second most important transshipment point in West Africa.

Processing

Senegal has three main tuna canneries, all located in Dakar and operated by joint Senegalese-French companies. The three canneries are the Societe Africaine de Produits Alimentaires (SAPAL), the Societe Nouvelles des Conserveries du Senegal (SNCDS), and the Societe Africaine d'Industrie de Bois (SAIB).

SAPAL, a subsidiary of the French firm Saupiquet, has a production capacity of 10,000 t per year. SAPAL, in spite of overall catch declines, was the only company of the three to expand its share of the tuna processing market in 1979 (Table 3). The decision by foreign vessels to sell most of the tuna they landed in Dakar to SAPAL accounted for much of the company's success in 1979. Spanish vessels sold almost 96 percent of their tuna landed in Dakar to SAPAL, whereas the previous year this tuna had been processed by SNCDS. SAPAL also canned over 50 percent of the tuna landed in Dakar by SOVETCO vessels.

SNCDS, with a production capacity of 10,000 t per year, saw its share of Dakar's tuna processing market decrease sharply in 1979. SNCDS was greatly affected by the 1979 catch declines and the Spanish decision to switch their tuna sales to SAPAL. SNCDS continued to process a large portion (37 percent) of SOVETCO's Dakar tuna landings, however.

SAIB, the third important processing company, has a production capacity of 3,500 t per year. SAIB handled the same percentage of the tuna canned in both 1978 and 1979. SAIB received 10 percent of the catch landed by SOVETCO vessels in 1979.

Exports

Almost all the tuna landed and processed in Senegal is exported, primarily to France. Tuna shipments to France totaled about 12,000 t (almost 99 percent) in 1978 and 11,300 t (almost 96 percent) in 1979. The Federal Republic of Germany purchased most of the remainder, about 150 t (1 percent) in 1978 and 550 t (4 percent) in 1979. Other European and African countries accounted for negligible quantities in both 1978 and 1979.

Senegal has deployed its three tuna purse seiners in the Eastern Pacific. The NMFS Division of Foreign Fisheries Analysis believes that much of the catch of these vessels in transshipped in Panama or Mexico and exported to the United States. Senegalese tuna exports to the United States were 8,750 t in 1979 (Table 4). During 1979, Senegal failed to provide the National Marine Fisheries

Table 4.—Senegal's tuna exports to the United States, by species, 1978-79.

Species	Exports to U.S. (t) 1978	1979
Yellowfin tuna	630	2,250
Skipjack tuna	1,050	6,500
Total	1,680	8,750

Source: U.S. Department of Commerce, Bureau of the Census.

Service (NMFS) with the information necessary to ascertain whether its purse seiners were fishing in a manner that did not result in porpoise mortality greater than that allowed U.S. fishermen. As a result of NMFS' inability to determine compliance with U.S. regulations, the United States embargoed further Senegalese exports of yellowfin tuna in February 1980.

Foreign Fishing and International Agreements

Senegal declared a 200-mile exclusive economic zone (EEZ) and a 150-mile territorial sea on 1 April 1976. To patrol these waters, Senegal purchased three fast patrol vessels in 1977 from the British company Fairey Marine Ltd. The patrol vessels, armed with a single 20 mm machine gun and 3 light machine gun mountings, were designed primarily for fisheries enforcement. Senegal licenses vessels of several countries to fish off its coast, but only Spanish and French fishermen catch tuna.

Spain and Senegal first signed a bilateral fisheries agreement in Dakar during 1975. In exchange for fishing rights Spain agreed to land a percentage of the tuna it caught in Senegalese waters at Dakar and to train a certain number of Senegalese fishermen. Senegal also received credits for the purchase of vessels and fishing equipment in Spain, and tuna processed in Senegal was allowed duty-free access to the Spanish market. Senegal was not satisfied with the terms of the agreement and, when it expired in June 1979, refused to renew it. After 6 months of negotiations, the two countries signed a new agreement in January 1980 in which Spain agreed to pay for fishing privileges rather than extend credits, and to provide technical assistance in fisheries development.

France and Senegal signed a bilateral fisheries agreement in Dakar in 1974. Under this accord, France loaned Senegal $9 million for fisheries development. All French fishing vessels, with the exception of sardine seiners, were required to purchase Senegalese licenses. French tuna vessels which did not land their catch in Senegal paid higher licensing fees than others, and Senegal's tuna exports were allowed duty-free entry into the French market. The French-Senegalese agreement was superceded in 1979 by Senegal's fisheries agreement with the European Economic Community (EEC).

The EEC and Senegal signed a fisheries agreement in June 1979 after the EEC assumed responsibility for the international fishery relations of its member states. The agreement was the EEC's first with an African country. Vessels of EEC-member countries were granted fishing rights in exchange for the payment of precisely defined fees and an EEC grant of $11.4 million for Senegal's fisheries development. Like the previous agreement with France, EEC fishermen who land their catch in Senegal pay a lower licensing fee. France is the only EEC member with tuna vessels deployed off Senegal.

The Soviet Union and Senegal maintained extensive fishery relations until 1976. The Senegalese state fishing company, SOSAP, created during the 1960's, received Soviet financial and technical assistance. In 1964, the Soviet Union and Senegal reached an agreement, formalized in 1965, whereby the U.S.S.R. agreed to provide $6.7 million in low-interest loans for the building of 10 tuna vessels and the construction of a tuna cannery in Dakar. Fishery relations between Dakar and Moscow deteriorated during the 1970's, however, and reached a low point when SOSAP went bankrupt in 1976. Much of the blame for SOSAP's financial failure fell on the Soviet Union, which was accused of having provided vessels that were too small and inefficient, required too many repairs, and were wholly unsuited to local fishing conditions. Reportedly, the catch of seven of the Soviet vessels was only 2,000 t of tuna in 78 days, compared with 2,450 t for a single French vessel in only 30 days. In addition, Senegal cited lengthy delays in delivery of the vessels as a reason for SOSAP's bankruptcy. The problems encountered by Senegal in its fishery relations with the Soviet Union are significant because the Soviet Union is building a fleet of tuna purse seiners which could be deployed off the coast of West Africa in the future. (Source: IFR-80/177.)

Norway Nabs Fish Law Violators

Of the 1,000 inspections of foreign fishing vessels undertaken by the Norwegian Coast Guard last year, 273 violations of the law were registered. Only 14, however, resulted in arrest and prosecution.

Danish fishermen headed the list of those who violated the fishing and zone regulations in 1980, but British and West German fishermen were also included. East Germans and Poles were more inclined to respect the law, according to the Norwegian Information Service. Most of the violations took place off the coast of south Norway.

The violations ranged from small offenses such as failing to keep records of catches and failing to report according to the fisheries regulations, to serious violations such as the use of prohibited equipment. This last category can include the use of fine-meshed nets or tightening of the trawl while fishing.

The chief of Norway's Coast Guard Inspectorate, Nils A. Tiltnes, reported that there were relatively few cases involving ships that have no right whatever to be in the Norwegian zone. However, in this year there have been a number of incidents of fishing vessels from EEC countries which have continued unlawful fishing in the Norwegian zone after the so-called EEC fishing was halted.

The majority of cases are minor offenses and the Norwegian Coast Guard

then gives an oral or written warning. Serious offenses result in arrest and the case is transferred to police authorities ashore. The Coast Guard consists of 14 ships and will receive three new ships this autumn. These new vessels will be the largest in the Norwegian navy and will carry British helicopters. Each ship will cost about U.S. $40 million.

The Distant-water Fisheries of Korea

The Republic of Korea's (ROK) most important fishing area is its coastal waters and the waters adjacent to its coastal waters in the Yellow Sea, the East China Sea, the Sea of Japan, and the Pacific Ocean (FAO statistical area 61). Until 1970, all of the Korean fisheries catch was taken in that area. Korea's first major distant-water fishing effort was tuna fishing in the Atlantic and the Southwest Pacific. By 1975, however, Korea had deployed its vessels on all major fishing grounds of the world, except in the North Atlantic.

The Korean fishing industry, like fishing industries in other distant-water fishing countries, has begun to show the impact of the enforcement of 200-mile zones by coastal countries. After several years of rapid growth, the ROK fisheries catch declined in 1978 (Table 1). The catch totaled only 2.35 million metric tons (t) in 1978, principally because the Soviet Union declared a 200-mile Exclusive Economic Zone (EEZ) in 1977 and expelled Korean fishermen from what had become an important pollock fishing ground for them. Nonetheless, the Northwest Pacific (FAO area 61) remains the ROK's most important fishing area, producing 80 percent of the total ROK catch. In 1978, ROK fishermen caught 1.9 million t of fish in FAO Area 61, which included 250,000 t of Alaska pollock, 200,000 t of filefish, 200,000 t of sardine and anchovies, and 80,000 t of flatfish and croakers.

Korea's most important distant-water grounds are the Central Atlantic (FAO statistical areas 31 and 34), the Northeast Pacific (FAO statistical area 67), the Southwest Pacific (FAO statistical area 81) and the Indian Ocean (FAO statistical areas 51 and 57).

Table 1.—Republic of Korea fisheries catch by FAO statistical area[1], 1970-78

Geographical area	FAO area[1]	Catch (× 1,000 t) per year								
		1970	1971	1972	1973	1974	1975	1976	1977	1978
Korea: in'and waters	04	0.5	0.9	1.5	1.6	1.3	8.8	15.0	25.9	32.9
Arctic	18									
Antarctic										
Atlantic	48									
Pacific	88									
Indian Ocean	58									
Atlantic										
Northwest	21							6.5	0.9	
Northeast	27									
W. Central	31		3.3	4.0	2.2	4.4	8.9	8.9	7.2	3.3
E. Central	34		39.9	40.1	64.2	75.5	97.2	105.0	99.0	94.3
Southwest	41						2.7	2.7	10.6	6.8
Southeast	47						1.9	1.8	0.3	
Pacific										
Northwest	61	842.1	981.2	1,234.2	1,545.8	1,859.5	1,914.6	2,034.7	2,029.5	1,914.0
Northeast	67						3.3	109.2	64.1	116.6
W. Central	71						1.6	16.5	15.6	16.5
E. Central	77						8.4	31.9	24.7	12.2
Southwest	81		30.3	40.5	43.6	44.3	38.5	25.7	66.3	54.3
Southeast	87							0.05	0.2	17.8
Mediterranean[2]	37							1.4		
Indian Ocean										
Western	51		16.8	21.0	26.4	38.4	35.1	30.0	60.4	63.2
Eastern	57						12.8	16.6	14.3	18.8
Total[3]		842.6	1,072.4	1,341.3	1,683.8	2,023.4	2,133.4	2,405.3	2,419.0	2,350.8

[1]Source: FAO "Yearbook of Fishery Statistics," 1975 and 1978.
[2]Includes the Black Sea.
[3]Totals may not agree due to rounding.

Central Atlantic

ROK catches in the Central Atlantic, primarily off West Africa, totaled 97,600 t in 1978. Most of the catch was tuna and billfish (32,000 t), and octopus and squid (31,000 t).

Northeast Pacific

ROK catches in the Southwest Pacific, primarily off New Zealand, declined in 1978 to 54,300 t. Tuna and squid groundfish stocks they could no longer fish in the Soviet 200-mile EEZ. ROK catches during 1978 in this area totaled 116,000 t, a new record. However, the U.S. and Canadian 200-mile fishing jurisdictions extend over much of the rich fishing grounds of this area and the ROK must continue to receive allocations to fish within the U.S. and Canadian 200-mile zones if it is to maintain this fishery.

Southwest Pacific

ROK catches in the Southwest Pacific, primarily off New Zealand, declined in 1978 to 54,300 t. Tuna and squid (20,000 t) are the most valuable species caught. Miscellaneous demersal and pelagic species provide another 34,000 t of fish. The ROK fishery in this area will probably decrease as foreign fishing is phased out by the New Zealand Government.

Indian Ocean

The ROK fleet caught a record 82,000 t of fish in the Indian Ocean during 1978, more than 80 percent of which was tuna and billfish. While Korean tuna longliners are deployed throughout the Indian Ocean region, the only countries within whose claimed waters ROK fisherman operate with the consent of the coastal country are the Seychelles and Australia. (Source: IFR-81/28.)

New NMFS Scientific Reports Published

The publications listed below may be obtained from either the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402, or from D822, User Services Branch, Environmental Science Information Center, NOAA, Rockville, MD 20852. Writing to the agency prior to ordering is advisable to determine availability and price, where appropriate (prices may change and prepayment is required).

NOAA Technical Report NMFS Circular 439. Todd, Ruth, and Doris Low. **"Marine flora and fauna of the northeastern United States. Protozoa: Sarcodina: benthic foraminifera."** June 1981. 51 p.

Abstract

An illustrated key to nearshore and shelf species includes 133 taxa. Seventy-nine genera are represented. In an annotated list, the distribution and ecology of each species are recorded within the area of Cape Hatteras to Nova Scotia and out to a depth of 50 m on the continental shelf. The key is intended to aid the nonspecialist in identification of the species to be expected in the marshes, estuaries, littoral zone, bays, and inner parts of the continental shelf.

NOAA Technical Report NMFS Circular 440. Bush, Louise F. **"Marine flora and fauna of the northeastern United States. Turbellaria: Acoela and Nemertodermatida."** July 1981. 71 p.

Abstract

This manual contains an introduction to the general biology, an illustrated key to the genera, and an annotated systematic list of the orders Acoela and Nemertodermatida. The key facilitates identification of 16 families and 75 genera of Acoela and includes the 3 genera of the order Nemertodermatida. The systematic list includes 173 species which have been described from the North Atlantic, including some more southern species that might be encountered here, and gives the habitat and known distribution for each species.

Some Aspects of the History of Oceanography

"Oceanography The Past," edited by Mary Sears and Daniel Merriman has been published by Springer-Verlag New York Inc., 44 Hartz Way, Secaucus, NJ 07094. This huge 812-page volume springs from the Third International Congress on the History of Oceanography, organized under the auspices of the Woods Hole Oceanographic Institution (WHOI) at Woods Hole, Mass., 22-26 September 1980. The Congress was also a part of the year-long celebration of the Fiftieth Anniversary of the founding of the Institution.

Of the presentations, some 69 were preselected for publication, ranging from several commentaries on WHOI to "Gondwanaland in ancient Indian literature." The topics presented were widely diverse, and the editors have presented them in about the order given—not grouped into particular categories.

An idea of this diversity can be had from some of the titles: The Benjamin Franklin and Timothy Folger charts of the Gulf Stream; Sebastos, the harbor complex of Caesarea Maritima, Israel; siting and development of Mediterranean harbors in antiquity; traditional Chinese ichthyology and its encounter with Jesuit science; Switzerland's contributions to the aquatic sciences over the centuries; the Victorian aquarium in ecological and social perspective; phytoplankton ecology before 1900; considerations on the medical use of marine invertebrates; the *Meteor* Expedition, an ocean survey; Belgium and the early development of modern oceanography; oceanography development in Peru; early observations and investigations of El Niño: the event of 1925; studies and acceptance of plate tectonics; on the environment and unity in marine research; the history of chlorinated hydrocarbon pollution; marine industrial pollution; studies of the Kuroshio and the Oyashio; North Pacific sea surface temperature observations: a history; mesoscale spatial distribution of plankton; and more.

The quality of the papers vary, as might be expected. Some of the authors were, of course, major figures in shaping these historical events and their contributions provide unique insights into their roles and those of their associates and predecessors. Other presentations are more routine, but in sum the volume helps to document the development of a variety of aspects of a rapidly developing field. It will be of great interest to not only students and teachers but to oceanographers and historians. Indexed, the hardbound volume costs $37.50 and is available from the publisher.

Seine Net Gear and Its Use

"Seine Fishing," subtitled "bottom fishing with rope warps and wing trawls," is a revision of the volume "The Seine Net—its origin, evolution and use," published in 1969. The changes since the late 1960's have been many, i.e., vessel size, power, electronic and mechanical sophistication, etc. The new volume, published by Fishing News Books Ltd., 1 Long Garden Walk, Farnham, Surrey, England, is authored by David Thompson, a successful Scottish skipper who has trained fishermen around the world for 18 years.

Again, the new volume presents the history and development of the Danish seine and its spread to England, Scotland, Ireland, Sweden, Norway, Iceland,

Russia, Australia, New Zealand, Canada, and the United States. Details are given on the adaptation of the gear to differing needs. Other chapters discuss the Danish anchor-dragging method of seining, Japan's tow-dragging method, fly-dragging, a chapter on seine net designs and gear, vessels and equipment, anchor seiner deveopment, seine net fishing in Scotland, and, finally, costs and earnings of British seine-net vessels.

Updated and indexed, the 224-page volume contains 114 illustrations plus a short bibliography of other books and articles on seine nets and fishing. Practical and useful, the book is available from the publisher for £14.50 plus £1.45 postage and handling.

Mysid, Euphausiid Biology Reviewed

Volume 18, **"Advances in Marine Biology,"** is devoted to "The Biology of Mysids and Euphausiids" by John Mauchline of the Dunstaffnage Marine Research Laboratory, Oban, Argyll, Scotland. The series, published by Academic Press Inc., 111 Fifth Avenue, New York, NY 10003, is edited by J. H. S. Blaxter, Sir Frederick S. Russell, and Sir Maurice Yonge. Superficially similar and once lumped together as the Schizopoda, mysids and euphausiids are now recognized as peracarid and decapod crustaceans, respectively.

Part One of this volume (p. 1-369), "The biology of mysids," introduces the species (780) and presents a key to the genera. It does not, however, contain a treatise on mysid taxonomy, instead, referring readers to appropriate literature. Following chapters review mysid larvae and reproduction, vertical distribution and migration, the gut, food and feeding, chemical composition, internal anatomy, physiology and responses to physical-chemical parameters of the environment, behavior, population dynamics, geographical distribution, predators and parasites, and mysids in the marine economy. Extensive references are provided. Three appendices present a taxonomic list of mysidacea and a classified list of literature for each genus and for geographical regions.

Part Two, "The biology of euphausiids" (p. 371-637), reviews information on the biology of these species published between 1968 and 1978. Volume 7 of the Advances reviewed that data up to 1968. Part Two follows the format of that earlier work so it can be easily cross-referenced.

The author reports 85 species of krill, unchanged since 1969, some of which are becoming commercially important. Newer data is presented on the species of krill, their distribution and synonymy, larvae, vertical distribution and migration, food and feeding, chemical composition, vision and bioluminescence, internal anatomy and physiology, growth, maturity and mortality, ecology of distribution, predators and parasites, and their place in the marine economy.

Addenda to the biology of euphausiids and mysids (p. 596-637) presents data from papers published since the manuscripts were completed. Likewise, the data are treated under the same chapter number and headings of the main papers to facilitate cross-referencing. Taxonomic and subject indexes are provided for the volume.

The 680-page volume, a comprehensive and valuable updating of data on the mysids and euphausiids, contains 94 figures (Part One, 63; Part Two, 31) and 67 tables (41 and 26). Priced at $89, it is available from the publisher.

Data on the Columbia River Estuary

The Columbia River estuary, the nation's ninth largest, is a highway of commerce and for commercially and recreationally important fishes. Anticipating future studies and development there, the Columbia River Estuary Data Development Program (CREDDP) has surveyed the known scientific literature on it and produced three publications relating to its fisheries. They are **"A Literature Survey of the Columbia River Estuary, Volume 1, Summary," "Volume II, Annotated Bibliography,"** and a historical view titled **"Columbia's Gateway, A History of the Columbia River Estuary to 1920."** The first two were prepared under contract with the Pacific Northwest River Basins Commission, and the last, done by the Oregon Historical Society, places the river's immense salmonid fisheries in perspective with its other resources, navigation, estuarine development, and early exploration.

Besides publications specifically devoted to the Columbia River estuary, the "Literature Survey" includes many references to other studies pertinent to Columbia River research efforts, regardless of where conducted.

Volume I (63 pages, looseleaf) reviews the extent (or lack) of data on the estuary from the Pacific Ocean to the eastern tip of Puget Island, at River Mile 46, by subject: Emergent plant production, benthic primary production, water column primary production, zooplankton and larval fishes, benthic infauna, epibenthic organisms, nonsalmonid fishes, salmonid fishes, avifauna, marine mammals, wildlife, current studies, and sedimentation.

Volume II contains the annotated references, listed by the same subjects and indexed by key words. The 430-page volume (looseleaf) will be of primary interest to the scientific community and researchers dealing with the Columbia River studies and to others interested in estuarine problems.

"Columbia's Gateway," a 65-page paperbound volume, gives a history of the region, its early development and navigation and includes a chapter on the river's immense salmonid fisheries. Appendix C presents 45 maps of early estuary development, hydrographic surveys, exploration, and the river's fisheries. The book includes historical notes and a bibliography, and costs $13. Volumes I and II of the "Literature Survey" cost $3 and $6, respectively, and all can be ordered from the Pacific Northwest River Basins Commission, CREDDP Publications, P.O. Box 908, Vancouver, WA 98666.

Editorial Guidelines for *Marine Fisheries Review*

Marine Fisheries Review publishes review articles, original research reports, significant progress reports, technical notes, and news articles on fisheries science, engineering, and economics, commercial and recreational fisheries, marine mammal studies, aquaculture, and U.S. and foreign fisheries developments. Emphasis, however, is on in-depth review articles and practical or applied aspects of marine fisheries rather than pure research.

Preferred paper length ranges from 4 to 12 printed pages (about 10-40 manuscript pages), although shorter and longer papers are sometimes accepted. Papers are normally printed within 4-6 months of acceptance. Publication is hastened when manuscripts conform to the following recommended guidelines.

The Manuscript

Submission of a manuscript to *Marine Fisheries Review* implies that the manuscript is the author's own work, has not been submitted for publication elsewhere, and is ready for publication as submitted. Commerce Department personnel should submit papers under completed NOAA Form 25-700.

Manuscripts must be typed (double-spaced) on high-quality white bond paper and submitted with two duplicate (but not carbon) copies. The complete manuscript normally includes a title page, a short abstract (if needed), text, literature citations, tables, figure legends, footnotes, and the figures. The title page should carry the title and the name, department, institution or other affiliation, and complete address (plus current address if different) of the author(s). Manuscript pages should be numbered and have 1½-inch margins on all sides. Running heads are not used. An "Acknowledgments" section, if needed, may be placed at the end of the text. Use of appendices is discouraged.

Abstract and Headings

Keep titles, heading, subheadings, and the abstract short and clear. Abstracts should be short (one-half page or less) and double-spaced. Paper titles should be no longer than 60 characters; a four- to five-word (40 to 45 characters) title is ideal. Use heads sparingly, if at all. Heads should contain only 2-5 words; do not stack heads of different sizes.

Style

In style, *Marine Fisheries Review* follows the "U.S. Government Printing Office Style Manual." Fish names follow the American Fisheries Society's Special Publication No. 12, "A List of Common and Scientific Names of Fishes from the United States and Canada," fourth edition, 1980. The "Merriam-Webster Third New International Dictionary" is used as the authority for correct spelling and word division. Only journal titles and scientific names (genera and species) should be italicized (underscored). Dates should be written as 3 November 1976. In text, literature is cited as Lynn and Reid (1968) or as (Lynn and Reid, 1968). Common abbreviations and symbols such as mm, m, g, ml, mg, and °C (without periods) may be used with numerals. Measurements are preferred in metric units; other equivalent units (i.e., fathoms, °F) may also be listed in parentheses.

Tables and Footnotes

Tables and footnotes should be typed separately and double-spaced. Tables should be numbered and referenced in text. Table headings and format should be consistent; do not use vertical rules.

Literature Citations

Title the list of references "Literature Cited" and include only published works or those actually in press. Citations must contain the complete title of the work, inclusive pagination, full journal title, the year and month and volume and issue numbers of the publication. Unpublished reports or manuscripts and personal communications must be footnoted. Include the title, author, pagination of the manuscript or report, and the address where it is on file. For personal communications, list the name, affiliation, and address of the communicator.

Citations should be double-spaced and listed alphabetically by the senior author's surname and initials. Co-authors should be listed by initials and surname. Where two or more citations have the same author(s), list them chronologically; where both author and year match on two or more, use lowercase alphabet to distinguish them (1969a, 1969b, 1969c, etc.).

Authors must double-check all literature cited; they alone are responsible for its accuracy.

Figures

All figures should be clearly identified with the author's name and figure number, if used. Figure legends should be brief and a copy may be taped to the back of the figure. Figures may or may not be numbered. Do not write on the back of photographs. Photographs should be black and white, 8- × 10-inches, sharply focused glossies of strong contrast. Potential cover photos are welcome but their return cannot be guaranteed. Magnification listed for photomicrographs must match the figure submitted (a scale bar may be preferred).

Line art should be drawn with black India ink on white paper. Design, symbols, and lettering should be neat, legible, and simple. Avoid freehand lettering and heavy lettering and shading that could fill in when the figure is reduced. Consider column and page sizes when designing figures.

Finally

First-rate, professional papers are neat, accurate, and complete. Authors should proofread the manuscript for typographical errors and double-check its contents and appearance before submission. Mail the manuscript flat, first-class mail, to: Editor, *Marine Fisheries Review*, Scientific Publications Office, National Marine Fisheries Service, NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115.

The senior author will receive 50 reprints (no cover) of his paper free of charge and 100 free copies are supplied to his organization. Cost estimates for additional reprints can be supplied upon request.

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